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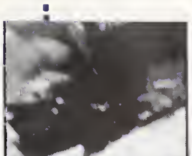



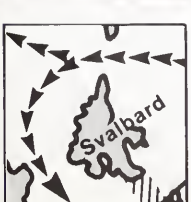




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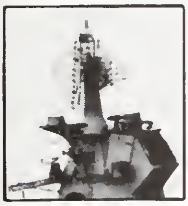


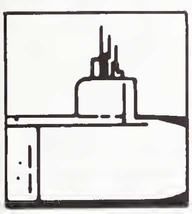

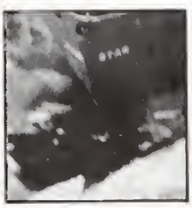
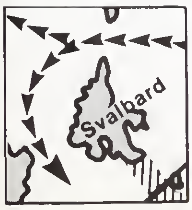




## profile



## history



## concerns



**Cover:** A U.S. nuclear attack submarine, the *City of Corpus Christi*, at sea. Front and back cover photos courtesy of General Dynamics, Electric Boat Division.

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# comment

There is a heated debate under way between government agencies on the question of classification of some research data—an issue bearing on national security and scientific inquiry. Part of this complex dispute directly affects marine science.

The classification dispute concerning the oceanographic community centers on mapping the 200 nautical miles offshore that fall within the U.S. Exclusive Economic Zone (EEZ) created in 1983 by President Reagan (see *Oceanus*, Vol. 27, No. 4). The National Oceanic and Atmospheric Administration (NOAA) wants to publish a series of systematic, detailed topographic charts of the EEZ. The mapping will be carried out by ships equipped with Seabeam—a declassified, commercial version of a sonar system developed many years ago by the U.S. Navy—and sophisticated navigational systems. The Department of Defense (DoD) wants to classify the data generated by the survey on the grounds that such detailed maps could be useful to commanders of enemy submarines.

The Seabeam system is already installed on several foreign and U.S. ships, among them the Woods Hole Oceanographic Institution's *Atlantis II*. In general terms, it consists of narrow-beam sonar instruments mounted on a ship's hull that, by computer analysis, can produce extremely precise topographic maps of the ocean floor. However, it's not just the precision of the Seabeam maps that is causing the problem. The DoD fears that the NOAA Seabeam charts, with their highly accurate control, might be matched with echo-sounding data produced by foreign submarines, which could with bathymetric correlation give precise (longitude and latitude) navigation fixes for missile guidance systems tracking U.S. hardened military targets. As mentioned, several foreign ships already are equipped with the Seabeam technology. And it should be recalled that President Reagan specifically said in establishing the EEZ that the United States would not assert jurisdiction over marine research in the zone. Classification of U.S. data thus might prompt similar action by countries with EEZs of scientific interest to the United States.

Economically, the Seabeam charts could be valuable for such activities as mineral prospecting, siting of seabed structures, or locating promising fishing areas. In science, Seabeam-produced data are already used, for example, in detailed studies of the interaction between currents and sediment deposition which is one of the principal factors in the dispersal and fate of wastes in the ocean.

The dispute—which pits the Navy and the Defense Mapping Agency as well as the DoD against NOAA—was put before the Naval Studies Board of the National Academy of Sciences in January for resolution. At this point, members of the oceanographic community found themselves in somewhat of a "Catch-22" situation, as the Department of Defense's reasons for objecting to the mapping were themselves classified, which made it difficult to respond openly to the DoD's concerns.

In late March, however, an *ad hoc* committee of the Naval Studies Board, chaired by David W. Hyde, reached the conclusion that there is a legitimate potential danger to U.S. national security interests in mapping some areas of our continental shelf. The committee, however, suggested that the charts might be released openly to the public if the data in critical topographical areas were "filtered" or smoothed of relief details in the 10 to 1,000 meter range. In a letter accompanying the committee's report to Frank Press, President of the National Academy of Sciences, Hyde wrote:

> "After reviewing NOAA's plans and the National Operations Security Advisory Committee (NOAC) concerns, the committee agreed with the specific contention that the proposed depth contour resolution (10–20 meters) and geodetic precision (50–100 meters) of the EEZ regional bathymetric charts would, if openly disseminated, provide a new option for precise navigation fixes by foreign submarines. . . . With this capability, missile firing submarines could potentially threaten the United States from broad areas inside the EEZ . . .
>
> "Conversely, the committee was less convinced by the other more general arguments for classification. However, given this specific concern, the committee concluded that a conflict exists between a significant national security interest, and academic community interests in open dissemination of these charts . . . for legitimate research of potential national benefit. Hence, some form of data management and dissemination control will have to be agreed upon between NOAA and DoD in order to balance the possible compromise to security against the benefits accruing from legitimate unrestricted use of the data.
>
> "The committee also believes that an administrative mechanism must be developed to provide for the selective release of . . . raw data from limited specific sites to support valid geophysical and oceanographic investigations or industry explorations. We envision that the wide range of possible requests will dictate the need for a case-by-case review procedure, where the benefits of the investigations requiring the data are assessed against the security concern.
>
> "Adopting such restrictions is contrary to the general principles of free exchange of information, on which the scientific progress of the United States is largely based. However, the committee noted during its deliberations that controlled, selective dissemination of environmental data has been successfully administered in numerous other similar instances. While academic interests may be somewhat impeded by this compromise, a useful balance can be struck which adequately protects national security."

In a letter sent with the committee's report to George A. Keyworth, Science Advisor to the President, Press noted that the Navy's concern might diminish with time, and recommended that the classification issue be reviewed at 2-year intervals. We heartily endorse the idea of regular, periodic reviews of this impediment to science and to the economic development of the EEZ for the future benefit of all.

**Paul R. Ryan**
**Editor, *Oceanus***

## *Introduction:*

# The U. S. Navy— A Functional Appraisal

### by Admiral James L. Holloway III, USN (Ret.)

Most rational people would agree that the United States needs a navy. But what kind of a navy should it be? And how large? In recent times, with the exception of strategic arms discussions, this has probably been the most important national security issue debated in the high policy councils of the federal government.

For example, in 1979, President Carter, in an unprecedented action, vetoed the Military Authorization Bill solely because it included a nuclear powered aircraft carrier that had not been contained in his naval shipbuilding program. This decision and the action of Congress the following year restoring the carrier (with sufficient votes to override a Presidential veto) are indicative of the strong feelings and differing views that surround the questions of how the fleet should be structured and how large it should be.

Unfortunately, in most cases, the wrong issues are argued: nuclear power versus oil, vertical take-off aircraft versus conventional carrier planes, projection forces versus a sea control fleet. These are largely peripheral questions, stemming from programming decisions and philosophical positions. The key questions relating to fundamental issues have been obscured.

The key questions should be: Why does the United States need a navy? What kind of a fleet is required to fulfill that need? To answer these requires an examination of fundamental national maritime requirements, and then development of these abstract concepts into actual operating forces.

The first question can be answered by a simple statement—the United States needs a navy to insure maritime superiority for our nation and our allies. As long as the United States remains a leader of the free world, it must be able to keep its friends, support its allies, defend its own interests, and maintain free access to the world's markets and sources of raw materials and energy.

To do all this means that the United States must be able to use the high seas whenever and wherever it finds it necessary. To assure continued access to world seas requires a navy that is powerful enough to deter or defeat any threat to that access. This is maritime superiority.

These principles and this logic are not new. They are so basic that they constitute the operative phrases of Title 10, U.S. Code, which sets forth the mission of the U.S. Navy: ". . . To gain and maintain general naval superiority . . . to establish and maintain local superiority . . . ."

The Navy carries out its mission within the framework of a national strategy—that is, in joint operations with the U.S. Army and Air Force, and in combined planning with our allies.

For the execution of these responsibilities, the Navy requires ships, aircraft, and people. It requires warships and combat planes capable of prevailing over the most modern and advanced weapon system technology that may be available to a potential enemy. Prevailing includes consideration of the Soviet Union's penchant for using surrogates to fight its wars with first-line Soviet equipment (such as advanced surface-to-air missiles, which, in Syrian hands, shot down two U.S. Navy aircraft in 1984 during Sixth Fleet operations off Lebanon).

The Navy must be staffed with competent professionals who can not only operate complex weapons systems, such as supersonic all-weather fighter aircraft and nuclear submarines, but maintain and repair them as well.

Then there must be enough of these modern and capable warships and aircraft to constitute an operating fleet able to defeat any naval threat, the largest of which is the Soviet Navy.

Detailed determination of specific naval requirements—that is, the military characteristics of individual ships and aircraft and the numerical force levels (which as a whole equal what is called "force

structure"), is based on two fundamental considerations: our national military strategy and any potential hostile threat. The basic formula thus is: naval requirements are those resources needed to support the force structure that in turn enables the U.S. Navy to carry out its responsibilities as expressed by the overall military strategy of the United States, especially as regards any threat represented by the maritime power of the Soviet Union and its allies.

**The National Military Strategy**

The United States has adopted a forward military strategy. In the Western Hemisphere, North America is virtually an island. The United States shares the continent with only Canada, Mexico, and Central America. The main body of our nation has only two international borders, without a potential threat to our basic security behind either one. On the other hand, two of our 50 states, all of our territories, and 40 of the 42 nations with whom we have treaties or security arrangements lie overseas.

The U.S. forward strategy thus uses the oceans as barriers in the defense of our homeland, and as avenues for extending our influence abroad. It exploits the principle that in general war we intend to engage an enemy closer to his border than to ours. This forward strategy depends on overseas allies, forward deployed military forces, and the mobility to respond to crises around the world. We want to be able to resolve minor crises before they become shooting conflicts, and a full-blown threat to our national security.

The Navy's roles in a forward collective defense are three-fold: First, to provide the sea-based segment of the strategic triad—ballistic missile submarines (their virtual invulnerability makes them a credible strategic retaliatory force). Second, to provide the naval arm for the U.S. armed forces deployed overseas, such as the Sixth Fleet in the Mediterranean, and the Seventh Fleet in the Western Pacific and Indian Ocean. And third, to protect the sea lanes—the lines of communication between the United States and our overseas allies, and our own forward deployed forces.

In addition to the 40 overseas nations with whom we maintain national security arrangements, the United States maintains four Army divisions in Germany, another in Korea, and a Marine Division in Japan. In time of war, our allies and our overseas forces need to be reinforced and resupplied. The remaining 13 active U.S. Army and Marine ground divisions are located in the United States. Should war break out, they most likely will have to be transported overseas.

Thus, the United States must be able to control the seas—not all seven-tenths of the Earth's surface that is covered by water, but those ocean areas needed for the specific requirements of our national security plans.

For our strategic forces, only a minimum of sea control is necessary, just enough to deny hostile anti-submarine units easy access to ocean areas, where, if they were concentrated in strength, they might harass or inhibit our own patrolling ballistic missile submarines.

For those general purpose naval units committed to the support of U.S. and allied ground troops, such as the Sixth Fleet in its North Atlantic Treaty Organization (NATO) role of Strike Force South, control of the sea must be initially established to provide relatively secure operating areas from which air strikes can be launched against targets ashore, or amphibious operations conducted, such as sending Marine units into battle.

Finally, the United States must be able to control vital sea lanes: in the North Atlantic between the United States and Western Europe; in the Mediterranean between the Atlantic approaches and the southern NATO powers (Italy, Greece, and Turkey), and Israel and Egypt; along the East and West Coasts of North America; along the East and West Coasts of South America in the event that the Panama Canal were to be disabled; to Japan from the United States; and between the Persian Gulf and Western Europe.

**Naval Functions**

Clearly, if our national military strategy is to succeed, the main function of the U.S. Navy must be to gain and maintain control of certain key ocean areas. All other responsibilities of the U.S. Navy, except for strategic warfare (which is a unique—and one time—case), are not only subordinate to the sea control function, but can only be effected after control of the sea has been established. Sea control, a term often used and too frequently misused, deserves a brief explanation.

Sea control is the prevention of another power from interfering with our use of the seas. It is accomplished by eliminating all threats to our use of the sea, either by destroying hostile submarines, surface ships, and aircraft, or by deterring (by threat of attack) hostile craft from entering those ocean areas we intend to protect.

In wartime, destruction rather than deterrence is the preferred course of action. Destruction eliminates the enemy's resources for waging war at sea. Deterrence simply holds hostile forces at bay and does not necessarily prevent them from being used at another time or another place, or for other military purposes.

The destruction of enemy ships and aircraft is most efficiently accomplished by striking them at their bases where the ships are immobile, the submarines on the surface, and the aircraft on the ground. The effectiveness of the Japanese attack on Pearl Harbor and the Israeli strikes against the Egyptian air bases in the Middle East wars are classic demonstrations of this fundamental principle of warfare. Obviously, there is a great advantage in engaging enemy naval forces before they reach open ocean areas, where they must be searched out. Physical seizure of hostile bases is the ultimate extension of this principle, providing a double edged advantage: denying the base for the enemy's use, and making it available for our own exploitation. The striking of enemy forces at their bases and the destruction or seizure of the bases themselves is an essential strategic element of sea control. For example, the U.S. island-hopping campaigns in the

*Large aircraft carriers, such as the nuclear-powered* Dwight D. Eisenhower *(shown above), form the core of the battle group, the basic unit of the U.S. fleet. (U.S. Navy photo)*

Pacific in World War II were not for the ultimate purpose of taking territory, but for sea control: to gain control of the approaches to the Philippines and Japan.

### Global Considerations

How does the concept of a forward strategy influence the shape of the U.S. Navy? First of all, because of U.S. global political commitments, naval forces need to be continually deployed in overseas areas around the world. At any given moment, about a third of our ships are deployed overseas. For example, there are routinely more than 40 ships assigned to the Seventh Fleet, the operating area of which extends from the Western Pacific to the East Coast of Africa, an expanse of ocean three times the breadth of the United States.

To conduct sustained operations in such remote areas as the Indian Ocean, where the U.S. maintains only a single base at the island of Diego Garcia, our ships must be able to carry enough fuel to steam independently for 4,000 to 6,000 miles without refueling. They must have large magazine compartments to carry the missiles and munitions for sustained combat operations, because the nearest reload port may be 2,000 miles away. They must have the sea-keeping qualities to ride out long periods of bad weather; international politics are not seasonal, and there may be no friendly refuge ports in the vicinity of a crisis. And finally, our far-flung fleets must carry their tactical air power with them, because most of their time will be spent operating beyond the effective range of tactical air fields available to U.S. combat aircraft. If there is one lesson history has taught us, it is that naval forces cannot survive a modern air threat without local air superiority. As a result, the U.S. fleet tends to be characterized by relatively large warships with good range and combat endurance, organized around the aircraft carrier, which furnishes the tactical air power.

### Modern Naval Warfare

War at sea became three dimensional with the advent of airplanes and submarines. Naval warfare is no longer limited to the oceans, given high performance jet aircraft and sea-based long range ballistic missiles. The naval battle field is now global in extent.

This means that naval warfare has undergone a permanent change from the days when naval battles consisted of fights between individual surface ships or opposing battle lines. Naval warfare in the future will involve ships, aircraft, submarines, missiles, and land-based forces. These systems may engage one another simultaneously over enormous areas. In a single small theater of operations, such as the Mediterranean, one could expect virtually simultaneous engagements among surface ships,

*Only recently has the Soviet Union begun to develop sea-based air power. Shown here is the aircraft carrier* Novorrossiysk *on her maiden voyage in 1983. (U.S. Navy photo)*

carrier-based aircraft, land-based aircraft, land-based missiles, and submarines, as well as amphibious assaults against shore bases. In addition to this panoply of conventional forces, ballistic missile submarines would be ready to launch their strategic missiles in the event the conflict escalated to nuclear war. And there would be antisubmarine warfare forces of both sides held in reserve to attack the strategic submarine forces should the chance of a nuclear exchange become imminent or inevitable.

Naval warfare has become incredibly broad and complex since the early days of naval history (Table 1) when the objective of a naval battle was simply to send the hostile warship to the bottom by destroying its water-tight integrity. Naval warfare today is divided into a number of individual warfare "areas" and "tasks," which relate to both the primary and peripheral missions and functions of the Navy. Different kinds of weapon systems and platforms are utilized in these areas of naval warfare.

Some weapon systems and platforms, such as the aircraft carrier, may have a number of applications. Others, such as a mine countermeasures ship, may be very limited in capability. Ideally, multi-purpose weapon systems would appear to be the best investment. However, to be able to do all things at all levels of warfare can be very expensive. Therefore it has proved useful to have in the fleet a variety of platforms and weapon systems. In generating the composition of the combatant fleet, one theorem seems to govern.

**Table 1. The multi-dimensional nature of naval warfare.**

| | |
|---|---|
| ***STRATEGIC MISSILES*** | |
| Land-Based Ballistic Missiles: | |
| TITAN | 23 |
| MINUTEMAN | 1,000 |
| Total Air Force | 1,023 |
| Sea-Based Ballistic Missiles: | |
| POSEIDEN | 496 |
| TRIDENT | 144 |
| Total Navy | 640 |
| ***GENERAL PURPOSE FORCES*** | |
| ***TACTICAL AVIATION*** | |
| (Fighter/Attack Aircraft) | |
| Air Force | |
| Active | 1,782 |
| Reserve | 864 |
| Total Air Force | 2,646 |
| Department of the Navy | |
| Active Navy | 967 |
| Reserve Navy | 120 |
| Active Marine Corps | 422 |
| Reserve Marine Corps | 92 |
| Total Department of Navy | 1,601 |

Source: Annual report to Congress by the Secretary of Defense for FY '85.

Although a general war with the Soviet Union is less likely than a limited war such as Korea or Vietnam, the conflict with the Soviet Union is the one that we *must* win. Therefore a navy must be designed to

**Table 2. Naval warfare tasks and principal types of ships.**

| Warfare Tasks | Carrier | Surface Combatant | Submarine | | Amphibious | Maritime Patrol Aircraft | Support |
|---|---|---|---|---|---|---|---|
| | | | Attack | Strategic | | | |
| Fundamental Tasks | | | | | | | |
| ANTIAIR WARFARE | | | | | | | |
| Air Superiority | ● | | | | | | |
| Air Defense | ● | ● | | | | | |
| ANTISUBMARINE WARFARE | | | | | | | |
| Distant Operations | ● | | ● | | | ● | |
| Close Operations | ● | ● | ● | | | ● | |
| ANTISURFACE WARFARE | | | | | | | |
| Distant Operations | ● | | ● | | | ● | |
| Close Operations | ● | ● | ● | | | | |
| STRIKE WARFARE | | | | | | | |
| Nuclear | ● | ● | ● | ● | | | |
| Conventional | ● | | | | | | |
| AMPHIBIOUS WARFARE | | | | | | | |
| Vertical Assault | ● | | | | ● | | |
| Over the Beach | | | | | ● | | |
| Close Support | ● | ● | | | ● | | |
| MINE WARFARE | | | | | | | |
| Offensive | ● | | ● | | | ● | |
| Countermeasures | ● | ● | | | ● | | |
| Supporting Tasks | | | | | | | |
| SPECIAL WARFARE | ● | | ● | | ● | | |
| OCEAN SURVEILLANCE | ● | ● | ● | | | ● | ● |
| INTELLIGENCE | | | | | | | |
| Imagery | ● | | | | | | |
| Reconnaissance | ● | ● | ● | | | ● | |
| COMMAND, CONTROL AND COMMUNICATIONS (C3) | ● | ● | ● | | ● | ● | ● |
| ELECTRONIC WARFARE | ● | ● | ● | | ● | ● | ● |
| LOGISTICS | | | | | | | |
| Long Haul Resupply | | | | | | | ● |
| Local Resupply | ● | | | | | | ● |
| Repair | ● | | | | | | ● |

*The Trident submarine* Michigan *undergoing tests in Groton, Conn. (U.S. Navy photo)*

prevail over the Soviet Navy to the extent required for the attainment of our own national security objectives. This has one important corollary: if we design a navy that can defeat Soviet maritime forces, then we should have a navy that is capable of handling all of the lesser intensity conflicts and situations that might arise.

Table 2 illustrates naval warfare tasks and the principal types of ships. From this table, it can be understood why the aircraft carrier is today the centerpiece of the fighting forces of the U.S. Navy.

**The U.S. Fleet**

The organization of fleet battle strategy reflects the mission, functions, roles, and deployment of the U.S. Navy. Primary among these considerations is the ability to maintain maritime superiority for the United States and its allies in the face of the growing Soviet threat at sea. This is the main responsibility of the combatant ships and aircraft of the U.S. Navy. To accomplish the principal objective of the fleet, these warships and aircraft are organized into battle forces and battle groups that are integral parts of the task force organizations of the deployed fleets, such as the Sixth Fleet in the Mediterranean and the Seventh Fleet in the Western Pacific.

A battle group consists of a carrier, surface combatants, and submarines, operating together in mutual support with the task of destroying hostile submarines, surface, and air forces within the battle group's assigned area of responsibility. Battle groups are defined as integrated task groups capable of conducting offensive operations at sea against the combined spectrum of hostile maritime threats.

There must be enough of these battle groups to prevent Soviet maritime forces from disrupting allied lines of communication in both the Atlantic and the Pacific theaters. That does not mean the U.S. Atlantic and Pacific Fleets must each be able to defeat the total Soviet Navy standing alone. It is recognized that if the Soviets concentrate their naval forces in the Atlantic, we can do the same. We can in fact redeploy our naval forces more quickly than the Soviets because of their restrictive geographical situation.

Today the Navy's objective is to have 15 carrier battle groups. In addition, the active fleet must include the specialized and non-combat forces necessary to support these 15 battle groups. This means we need about 600 ships to carry out the job. Table 3 shows today's force levels and the composition of the fleet when the 600-ship Navy is achieved.

**The Soviet Threat**

The territory of the Soviet Union, spanning a continent, dominates Eurasia. On its southeastern flank lies the People's Republic of China; a border guarded by troops on both sides and prone to incidents. Arrayed along the western border are the countries of the Warsaw Pact, considered buffer states by the Soviet Union. Further to the west, still on the same continent, lie the North Atlantic Treaty Organization nations of Western Europe. Thus it is possible for the Soviet Union to defend itself from Chinese communists, support its Warsaw Pact allies, and invade Western Europe, *never having crossed* a *major body of water.* Why then do the Soviets have the largest navy in the world?

The answer, this author thinks, is to oppose

Table 3. The Navy's deployable battle forces today and projected through 1990.

| Deployable Battle Forces (End Fiscal Year) | FY 1980 | FY 1985 | FY 1986 |
|---|---|---|---|
| Ballistic Missile Submarines | 40 | 37 | 38 |
| Strategic Support Ships | 8 | 6 | 6 |
| Aircraft Carriers (Deployable) | 13 | 13 | 13 |
| Battleships | 0 | 2 | 3 |
| Cruisers | 26 | 30 | 32 |
| Destroyers | 81 | 69 | 69 |
| Frigates | 71 | 110 | 112 |
| Nuclear Attack Submarines | 74 | 96 | 95 |
| Diesel Attack Submarines | 5 | 4 | 4 |
| Amphibious Ships | 66 | 61 | 62 |
| Patrol Combatants | 3 | 6 | 6 |
| Mine Warefare Ships | 3 | 3 | 7 |
| Mobile Logistics Ships | 68 | 74 | 75 |
| Support Ships | 21 | 31 | 33 |
| Total | 479 | 542 | 555 |

| FY 1986–90 Shipbuilding Program | FY 1986 | FY 1987 | FY 1988 | FY 1989 | FY 1990 | FY 1986–90 Five-Year Total |
|---|---|---|---|---|---|---|
| New Construction | | | | | | |
| TRIDENT (Ballistic Missile Submarine) | 1 | 1 | 1 | 1 | 1 | 5 |
| SSN-688 (Attack Submarine) | 4 | 4 | 4 | 2 | 4 | 18 |
| SSN-21 (Attack Submarine) | — | — | — | 1 | — | 1 |
| CG-47 (Guided Missile Cruiser) | 3 | 3 | 3 | 2 | — | 11 |
| DDG-51 (Guided Missile Destroyer) | — | 2 | 5 | 5 | 5 | 17 |
| LHD-1 (Amphibious Assault Ship) | 1 | — | 1 | 1 | 1 | 4 |
| LSD-41 (Landing Dock Ship) | 2 | — | — | — | — | 2 |
| LSD-41 Follow-on (Landing Dock Ship) | — | — | 2 | 2 | 2 | 6 |
| MCM-1 (Mine Countermeasures Ship) | 4 | 1 | — | — | — | 5 |
| MSH-1 (Mine Hunter-Sweeper) | 4 | 4 | 4 | 4 | — | 16 |
| AOE-6 (Multipurpose Stores Ship) | — | 1 | 1 | 1 | 1 | 4 |
| AE-36 (Ammunition Ship) | — | — | 1 | 1 | 1 | 3 |
| AR (Repair Ship) | — | — | — | — | 1 | 1 |
| TAO-187 (Oiler) | 2 | 2 | 2 | 2 | 2 | 10 |
| TAGOS (Surveillance Ship) | 2 | 2 | — | — | — | 4 |
| Total | 23 | 20 | 24 | 22 | 18 | 107 |
| Conversions/SLEPs/Reactivations | | | | | | |
| CV (Aircraft Carrier) SLEP | — | 1 | — | — | 1 | 2 |
| BB (Battleship) Reactivation | — | 1 | — | — | — | 1 |
| LPD-4 (Landing Platform Dock Ship) SLEP | — | — | 1 | 3 | 3 | 7 |
| AO ("Jumbo" Oiler) Conversion | — | — | 1 | 2 | 2 | 5 |
| AG (Acoustic Research Vessel) Conversion | 1 | — | — | — | — | 1 |
| TAVB (Aviation Support Ship) Conversion | 1 | — | — | — | — | 1 |
| TACS (Crane Ship) Conversion | 3 | 2 | 2 | — | — | 7 |
| Total | 5 | 4 | 4 | 5 | 6 | 24 |

Source: SECDEF annual report to Congress, FY '86.

the U.S. Navy. For if the U.S. Navy can be defeated, the ability of the United States to control the sea is lost, our forward strategy becomes invalid, and the NATO concept collapses. The main support for our NATO allies must come from the United States by ship. The mechanization and fire-power of modern warfare requires such large quantities of combat consumables (fuel and ammunition) that reinforcement and resupply must come by ship.

### Strategic Mobility

According to the Joint Chiefs of Staff (JCS), "In any major overseas deployment, sealift will deliver about 95 percent of all dry cargo and more than 90 percent of all petroleum products" (JCS FY 1985 Posture Statement). This overwhelming reliance on sealift is understandable when one considers the enormous quantities of war materiel demanded by the mobility and fire-power of modern ground forces. For example, more than 100,000 tons of cargo are required to deploy a single mechanized division. When overseas, that division will need more than 1,000 tons a day delivered to sustain it in operations.

Airlift is planned for the rapid movement of troops to join up with prepositioned equipment, and for the fast delivery of small amounts of critical supplies and materiel. But airlift is severely limited in terms of its ability to move outsized equipment and in the total volume that can be lifted. A large portion of the equipment of modern armies, such as bulldozers, bridges, helicopters, and tank retrievers, will not fit in most aircraft. One modern container ship can deliver the equivalent cargo of 150 C-5 aircraft—and there are only 75 C-5s in the Air Force's inventory.

Also, airlift is a notorious consumer of fuel. According to the JCS, experience during the 1973 Yom Kippur War showed that six tons of aviation

## *Lessons Learned from the Falklands*

*Although there will probably never be a full agreement on the significance of the British experience in the Falklands, it is nevertheless clear that the principal lessons learned relate directly to our own naval policies.*

*What was the British experience in the Falklands? They fought a war 8,000 miles from home and 4,000 miles from their closest base, and they won it—just barely. According to statements made by the British military commanders themselves, there were two critical areas in which success could have turned to failure with just a slight shift in the fortunes of war. These two critical elements were air superiority and logistical support.*

*Although the British were able to turn back the Argentine air strikes eventually, it was not until six British ships had been lost. The margin of success was so thin that the commander of the British forces has said that if all of the Argentine bombs that had hit his ships had exploded, the damage to the invasion fleet would have been so severe that the British expeditionary force would have had to withdraw.*

*Without conventional aircraft carriers as we know them in the U.S. Navy, the British had to rely on a small number of V/STOL "jump jets" flying from a helicopter carrier and a through-deck cruiser. The small number of fighters, their limited performance, and the lack of radar warning planes so constrained the effectiveness of the fleet's fighter cover that the Argentine air strikes were able to penetrate with almost fatal success.*

*If local air superiority turned out to be the vital tactical factor, the most critical strategic consideration was sealift. There was no way that the British could mount an expeditionary force of the war fighting capability to even threaten the Falklands without total reliance on sealift. The troops and their weapons, and their sustaining combat supplies, could only be moved by ship. Air was out of the question. The nearest airfield was 4,000 miles away at Ascension Island. Everything would have to be brought in initially by ship, and the British did just that.*

*So the principal lessons learned from the Falkands campaign are:*

- *If a nation is to exert a military influence in an area of the world remote from friendly bases, the operation must be carried out by naval forces.*
- *To conduct successful military operations, a naval force must have clear-cut air superiority.*

*These two lessons learned from the Falklands confirm two important facets of our own naval policy:*

- *The renewed emphasis on sealift that prompted the Secretary of the Navy in 1984 to expand the two original functions of the Navy—sea control and power projection—to include the third function of sealift.*
- *The Navy's carrier program that maintains a force of large deck carriers capable of operating and supporting tactical aircraft with weapons systems superior to their potential adversaries so that local air superiority can be assured for whatever naval operations are contemplated.*

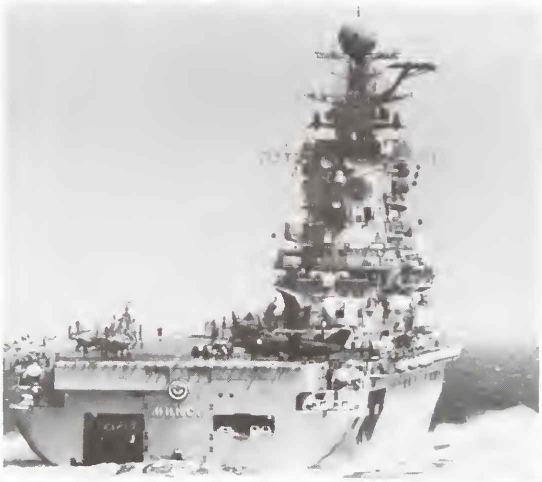
***—JLH***

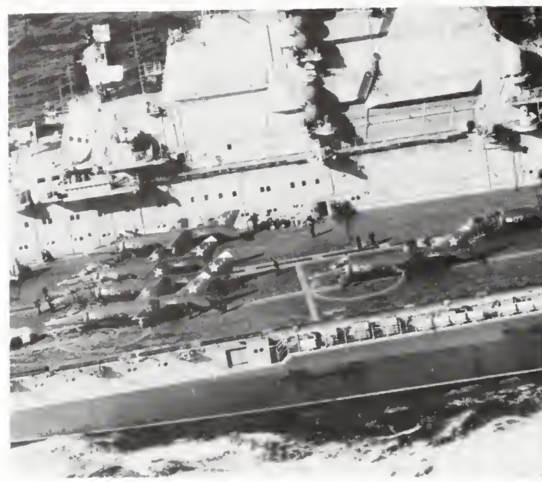
fuel was required for every ton of military cargo delivered to Tel Aviv in support of Israel.

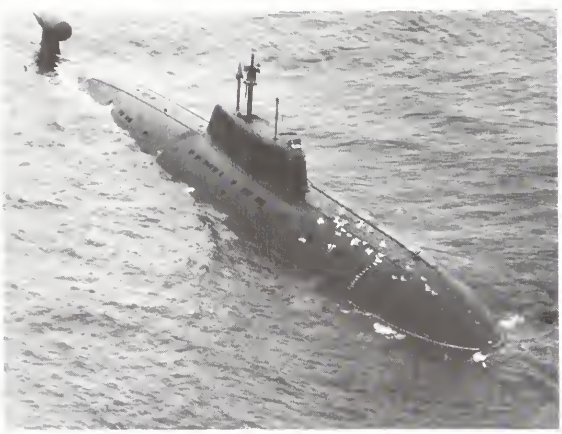
Prepositioning is not the answer. With today's reconnaissance techniques, the concentration of war materiel in the confined areas of Western Europe makes those depots vulnerable targets to Soviet tactical rockets and aircraft. It is the Navy's responsibility to move our combat forces and their support overseas. It is up to the U.S. fleet to protect the sea lines of communication and to prevent Soviet submarines, surface ships, and aircraft from interdicting our sealift. The Soviets clearly recognize this and have predicated their naval program on a seagoing force designed to defeat the U.S. Navy to the extent that we will be unable to defend the sea lanes and our overseas lines of communication.

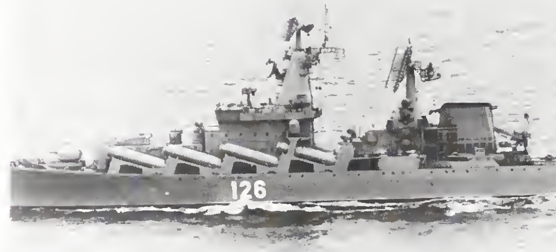
### The Soviet Navy

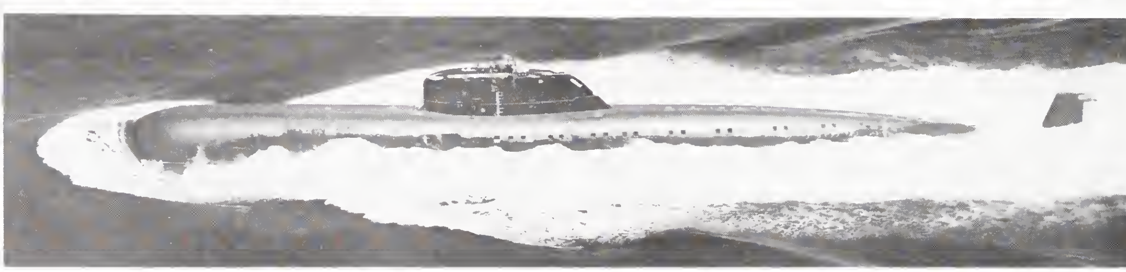
From a historical perspective, the Soviet Navy was originally designed for the defense of the homeland: antisubmarine forces to blunt the nuclear threat posed by our ballistic missile submarines; and long-range, land-based aircraft and a massive submarine fleet to defend against carrier airstrikes into European Russia and the Soviet Pacific bases. Then, in a technological sense, the Soviets scored a breakthrough. The development of anti-ship cruise missiles (air, surface, and submarine launched) met with considerable success. Soviet naval strategists were quick to realize that if the main battle forces of the United States could be neutralized with the anti-ship cruise missile, then the unarmed tankers, cargo carriers, and troop ships that constitute the overseas lines of communication through which we support our allies and our own army and air forces abroad would fall prey to their fleet. If the U.S. Navy's protective cordon could be breached, the large numbers of torpedo firing diesel submarines in the Soviet naval inventory would take on enormous added significance in the role of sea lane







*The Soviet Navy. From top: A nuclear powered guided missile cruiser; a* Kiev-class *aircraft carrier with Yak-36 aircraft on board; a Sierra-class nuclear powered attack submarine; an amidship view of the cruiser Slava showing cruise missile launch tubes; and a Charlie-class cruise missile submarine underway. (All U.S. Navy photos, except Sierra-class submarine courtesy of the Royal Norwegian Air Force)*

U.S. Navy F-14 Tomcat fighters on patrol. (U.S. Navy photo)

interdiction. So today, although the emerging naval strategy still affords protection of the homeland, the interdiction of the NATO lines of communications, achievable only through the neutralization of the U.S. Navy's battle forces—the carrier groups—is a strategic objective of rapidly growing emphasis.

In a comparative sense, the Soviet Navy is larger in numbers but lesser in individual unit capability than the American Navy (Table 4). But qualitatively, the Soviets are improving. Their ability to operate large modern warships, capable of waging three-dimensional naval warfare with the most modern weapons technology, in areas more and more remote from the Soviet heartland, is growing. Today the Soviet Navy has the ability to exercise control of the sea in areas contiguous to the U.S.S.R. and its allies. As sea-based tactical aircraft are added to the Soviet naval order of battle, as they are doing with Forger Vertical Take Off (V/STOL) aircraft on the *Kiev*-class carriers, it becomes only a matter of brief time before the Soviet Navy will have the ability for offensive sea control and the projection of power ashore. It is evident that Soviet ambitions are to develop a navy that can serve as a powerful instrument of national policy, as ours has for the past three decades, as well as a formidable threat to the validity of the United States concept of a forward collective security.

**Table 4. Soviet Navy active ships (1985).**

| | | |
|---|---|---|
| **Submarines** | | **380** |
| **Ballistic missile (nuclear) (1)** | **64** | |
| **Ballistic missile (diesel)** | **15** | |
| **Attack (nuclear)** | **114** | |
| **Attack (diesel)** | **164** | |
| **Auxiliary-Research** | **23** | |
| **Aircraft carriers** | | **3** |
| **Helicopter carriers** | | **2** |
| **Cruisers** | | **35** |
| **Destroyers** | | **68** |
| **Frigates** | | **32** |
| **Light surface combatants** | | **180** |
| **Fast patrol craft** | | **410** |
| **Amphibious ships** | | **78** |
| **Mine countermeasures ships** | | **135** |

*A U.S. Marine AV-8A Harrier light attack jet lifts off from U.S.S.* Tarawa *flight deck normally used by helicopters. (U.S. Navy photo)*

Unless the U.S. Navy can assure the movement of reinforcements and resupply overseas to our allies and our own forward deployed forces, our strategy of a forward collective defense will fail. If we were to lose naval superiority, the Soviets would be able to cut these strategic lines of communication, and our alliances with NATO, Japan, and Korea would be unsupportable. Then, the Soviets would have the opportunity to defeat us all on a piecemeal basis.

Unfortunately, the Soviets would not have to go to war to take advantage of a shift in maritime supremacy. If it were simply perceived by the Soviets, ourselves, or our allies that the balance of military power had shifted to the Soviets, both sides would know that our strategy of a forward collective security was no longer valid. Our alliances would crumble and U.S. national security would be in jeopardy.

*Admiral James L. Holloway III is a former Chief of Naval Operations (1974–1978) and member of the Joint Chiefs of Staff. He is presently chairman of the Council of American Ship Operators in Washington, D.C. During an illustrious service career, Admiral Holloway, a naval aviator, served in combat in World War II, Korea, and Vietnam, serving two tours of duty in the latter country as commanding officer of the U.S.S.* Enterprise, *the Navy's first nuclear powered carrier, and as commander of the U.S. Seventh Fleet. He also has had crisis assignments in the Middle East and has been awarded six Distinguished Service Medals.*

# *Naval Research and*

**by Rear Admiral J. B. Mooney, Jr., USN**

## Chief of Naval Research

To measure the importance of U.S. Navy research and development (R&D) programs and their relationship to national security, one need only reflect on a statement made in the mid-1970s by Soviet fleet Admiral Sergei G. Gorshkov at a time when the flag of the Russian Navy had begun flying over the oceans of the world:

> *. . . the disruption of the ocean lines of communication, the special arteries feeding the military and economic potentials of those [the enemy] countries, has continued to be one of the most important of the [Soviet] Navy's missions . . . sooner or later the United States will have to understand it no longer has mastery of the seas.*

What makes these statements critical is that they fly in the face of the mission of the U.S. Navy—to keep the sea lanes and lines of maritime communications open. They were said at a time when the Soviets were devoting more of their economy toward R&D than was the United States.

For the U.S. Navy to be properly equipped to face such challenges, to protect our national security, and to maintain the open channels of the oceans, it must rely on the technological predictions and achievements of our scientific and engineering resources, principally those of the Office of Naval Research (ONR) where scientific ideas take shape.

That's been the business of ONR since it was created on August 1, 1946, to act as a contracting agency to bring scientific research skills together from around the nation to meet urgent goals of national security. Scientists were encouraged to apply their talents and skills to whatever research projects interested them. Not until sometime later were proposals required to aim for technology and products of special interest to the Navy.

Supported by ONR funding, academic institutions expanded and strengthened national research capabilities, opening the way for dramatic new advances in technology. Since that auspicious beginning, ONR has remained at the cutting edge of science and technology, in service to the Navy and to the nation. It has funded research carried out under contract by universities, industrial establishments, nonprofit organizations, and by Navy laboratories, including ONR's own laboratories—the Naval Research Laboratory (NRL) in Washington, D.C., the Naval Oceanographic Research and Development Activity (NORDA) in Bay St. Louis, Mississippi, and the Naval Biosciences Laboratory (NBL) in Oakland, California.

*Admiral Mooney*

The Chief of Naval Research (CNR) reports directly to the Assistant Secretary of the Navy (Research, Engineering and Systems [ASN/R,E&S]), and provides R&D advice and financial services for management of the Navy-wide R&D budget. The CNR also oversees the Navy's Patent Program and administers the Naval Research Advisory Committee, a group of 15 eminent civilian scientists and engineers who advise the Secretary of the Navy, the Chief of Naval Operations, the Commandant of the Marine Corps, and the CNR on science relevant to the needs of the Navy and national security.

At ONR headquarters in Arlington, Virginia, some 30 naval officers and 400 civilian scientific

# National Security

*Arctic native drops by for a visit to an ONR research camp on an ice floe. (U.S. Navy photo)*

officers and support personnel, the managers and custodians of the Navy's basic research program, make up the ONR staff. As a team they manage about $350 million annually of R&D funding that Congress appropriates to the Navy for scientific research, research based on long-range Navy objectives and national security needs.

More than half of ONR's budget—56 percent—goes to the support of *basic* research conducted at universities in the United States. Thirty-six percent supports research at Navy laboratories, and the remaining 8 percent supports research at nonprofit institutions or industrial organizations. This commitment to the advancement of science and technology through support of basic research has the potential for improving naval operations and enhancing national security.

The policy of ONR is to use flexible contract and grant procedures in carrying out its program. Unsolicited proposals from qualified organizations help meet its mission objectives.

Through a Contract Research Program (CRP), ONR plans and supports basic research at the frontiers of science. From such advancement, ONR provides the knowledge necessary for the Navy to make informed decisions about further exploratory development. That, in turn, provides the technology base from which naval capabilities are drawn. In this way, ONR's Contract Research Program is the source of the best creative ideas and information in the physical, mathematical, environmental, engineering, and life sciences needed to optimize future naval operations.

Support for the Contract Research Program comes mostly from Navy research Category 6.1 funding, and indeed the CRP is responsible for managing about two-thirds of the Navy's Category 6.1 resources. The program has two components: Core Programs and Accelerated Research Initiatives, with resources split about evenly between the two components.

The Core Programs consist of long-term programs in the traditional scientific disciplines. Heavy weight is given both to scientific merit and technical approach, with particular emphasis on "new" science. The Core offers the possibility of examining new and burgeoning high-risk science areas. The Core also maintains a level of effort in scientific areas that are broadly associated with all areas of science, technology, and naval needs.

Accelerated Research Initiatives are designed to concentrate resources in specific areas of research that offer a particularly attractive opportunity for gaining significant advancement by increasing funding for the program. These programs are neither more applied nor more basic than the Core Programs; they represent an accelerated or enhanced program in a basic scientific area that is potentially attractive to future naval needs.

The strength and vitality of ONR's Contract Research Program depends, ultimately, on ideas originating from the research community—primarily through unsolicited proposals from U.S. universities. Those ideas are focused within the four areas mentioned previously: mathematical and physical sciences, environmental sciences, engineering

50 microns

50 microns

*A scanning electron micrograph of a cross section of an electrochemically made polymer. The view on the right shows the ductile character of the material which gives improved strength. (U.S. Navy photo)*

sciences, and life sciences.

### Mathematical and Physical Sciences

As an engineering-oriented service, the Navy is involved in mathematics and physical sciences on a broad scale. Mathematical sciences programs focus on such areas as mathematical analysis, computational architectures, and statistical methodologies.

Because of the nature of mathematics, research carried out by ONR investigators has broad implications for national security. A portion of the analysis program focuses on mathematical inverse problems. Mathematical inverse methods can be used to reconstruct ocean bottom profiles based on sonar data and even to reconstruct images that appear hopelessly blurred or noisy.

Other portions of the analysis program are focused on control methodology. Application of modern control theory to both aircraft and ship design results in vehicles with better performance and stability.

Statistical methods for signal processing have resulted in significant improvement in detection capability for undersea surveillance. Indeed, these methods have made sonar operation in the coastal margin and Arctic possible. Application of statistical methods to remote sensing data analysis has suggested ways to achieve improvement in handling large masses of surveillance data from space and has, in effect, sharply increased resolution from imaging sensors through improved image-processing techniques.

In addition to the previously mentioned areas, fundamental work is being done in discrete mathematics with particular application to communication networks, in the mathematical decision sciences with application to command and control, and in mathematical optimization with application to logistics, scheduling, and determination of force mixes.

Our research efforts in physics focus on optics, high-precision spectroscopy, atomic and molecular physics, surface and interface physics, physical acoustics, plasma physics, and radiation sources.

Three major thrusts are radiation sources, atomic clocks, and high current compact accelerators. Three regions of the spectrum for coherent radiation sources are short wavelength ultraviolet to soft X-ray, near infrared (IR), and far IR to microwave.

One approach to realizing a short wavelength laser involves the creation of highly excited ionized atomic species and subsequent stimulated reemission. Such sources could have application to lithography and the study of material properties.

An electrooptic countermeasures Accelerated Research Initiative that we are working on is designed to develop broadly tunable laser sources in the 3 to 6 micrometer region of the spectrum. Basically, two approaches are being considered. One is color center lasers and the other is semiconductor diode lasers. These new semiconductor lasers appear to have very interesting band gap properties that may make them tunable out to 20 to 30 micrometers. The application here is for decoying missiles that use infrared detectors for homing.

Approaches to realizing high power coherent radiation sources in the far IR to microwave region involve such concepts as free electron lasers and gyrotrons. These have important implications for surveillance and characterization of targets or other objects.

New concepts for atomic clocks based on trapping and cooling of neutral and ionic atomic species are being investigated. The search for trapping and cooling atomic ions has already produced ionic "clouds" cooled to milli-degree Kelvin and a crude stored ion clock of approximately the same accuracy as current state-of-the-art cesium beam devices. The Naval Observatory is now evaluating a stored ion atomic clock device. The first demonstrated cooling and trapping of neutral atoms was performed by ONR research. Applications of precision timing include high precision navigation and high-data-rate secure communications.

In the area of high energy compact accelerators, the primary concept being investigated is the modified betatron. The types of accelerators being considered here are to be distinguished from those of interest to high-energy physicists in that the latter accelerators involve micro- to nanoamperes, whereas those of interest in the current ONR research have 100 to 10,000 amperes or more. This means that collective phenomena, plasma instabilities, and new injection/ejection techniques must be evaluated. There are two possible applications. One is as endoatmospheric directed energy weapons, such as might be used in anti-ship missile defense. Another is as an electron beam source for free electron lasers.

Our efforts in chemistry focus on four major areas—polymeric materials, solid state and surface chemistry, synthesis and mechanisms, and electrochemistry.

Polymer research includes synthesis, characterization and processing work on high strength, environmentally stable structural materials, as well as materials for electronics applications, such as communications.

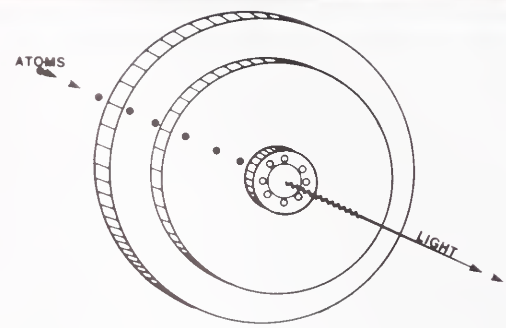
The solid state and surface work emphasizes the chemistry of electronic materials. Synthesis and mechanisms studies include research on decontamination of chemical warfare agents and routes to new antifouling coatings.

Finally, electrochemistry research emphasizes studies on materials for new high-energy, high-power density battery applications as well as solid state electrolytes for applications such as all-solid-state displays.

In the area of electronics, researchers are studying solid state materials and devices, systems theory, antennae, and propagation that might apply to advanced military systems, such as radar, communications, and electronic warfare.

Future needs for most, if not all, Navy electronic systems call for smaller, faster, and more reliable hardware. We are addressing this need through our solid state research by studying fundamental problem areas, such as defects in semiconductor materials, electrical contacts, and thin insulators.

We also need to know more about scattering of radar signals by targets. For instance, the radar detection problem intensifies in the face of stealth technology, which makes things harder to see on the radar scope. We need to know what happens to the signal when it hits a stealth target and we need to know how to recover information from the radar




*Cooling neutral atoms. This technique is part of the research under way in the development of atomic clocks. Here atoms are being stopped by a laser beam at the end of a solenoid. (U.S. Navy photo)*

return, using electronic signal processing techniques.

Another facet of electronics research is space environmental factors in which we are measuring radiation effects that have great influence on satellite communications.

**Environmental Sciences**

The Office of Naval Research's work in environmental research covers three areas—ocean engineering, ocean sciences, and geophysical sciences.

Ocean engineering research is developing solutions to Navy and Marine Corps problems, including location of sunken platforms, such as ships or planes. Basic research in this area is focused on devising a method to detect chemical plumes of jet fuel, transmission fluids, or other lubricants that leak from submerged ships or aircraft.

A second ocean search program is an ONR initiative known as *Argo-Jason*. This deep submergence system, capable of searching to 6,000 meters, combines acoustics and optics technology in a single towed system called *Argo* that can "ground truth" in real time a search area through a combination of acoustics and high-resolution, low-light television. The system covers a 5-kilometer swath acoustically and a 200-meter-square area visually with its TV cameras. The *Jason* vehicle includes a closeup stereo TV camera and advanced manipulator arms that can maneuver dexterously (see *Oceanus*, Vol. 25, No. 1, p. 30).

To ensure that the fleet can get to sea, ocean engineers, through the Navy's Depth Assurance

Program, study harbor flow and sedimentation processes to develop systems that will minimize harbor dredging maintenance requirements and improve harbor safety.

We are studying open ocean processes for leads to help us develop better predictive models of the ocean and the marine atmosphere. Here major advances are often dependent on new instruments. These are funded at about 15 percent of the total program but always under the direction of an investigator who needs the instrument to test a hypothesis and who will supervise its design, construction, and at-sea tests. Satellite remote sensing techniques play a major role in all programs.

Research in physical oceanography is conveniently divided into space scales. On the large ocean basin scale of more than 1,000 kilometers, studies include the dynamics of western boundary currents, such as the Gulf Stream, Kuroshio, and Agulhas, and of the central gyres, including thermocline ventilation. This work is required as the basic building block for numerical models of the ocean.

Mesoscale variability studies, at scales of 10 to 300 kilometers, look at the generation, evolution, and interactions of fronts and eddies, including topographic and atmospheric effects. This space scale is particularly important for predictions to support tactical naval sonar operations.

Small-scale phenomena with dimensions down to those of molecular dissipation include surface and internal waves, surface and bottom mixed layers, horizontal fine structure, salt fingering, and turbulence. These small-scale phenomena are of interest in exploring the potential of various non-acoustic antisubmarine warfare techniques. Although emphasis is on the open ocean, the effects of coastal boundaries, including beach processes, are studied on all scales.

The chemical oceanography program includes studies of the small-scale distribution of trace elements, such as copper, zinc, nickel, iron, gaseous hydrogen, and dissolved organic matter in the ocean. The photochemistry of the ocean's oxygen system and the related reactive species initiated by absorption of sunlight, are also under study. Ubiquitous organic slicks on the sea surface that potentially can affect satellite microwave remote sensor signals are also of particular interest.

Biological oceanographers are examining the processes controlling the distribution of biologic phenomena, such as bioluminescence, plankton, zooplankton, and fish. They also are investigating the processes that initiate and control biodeterioration and biofouling and the processes by which biological elements influence sea-floor properties and sea-floor morphology.

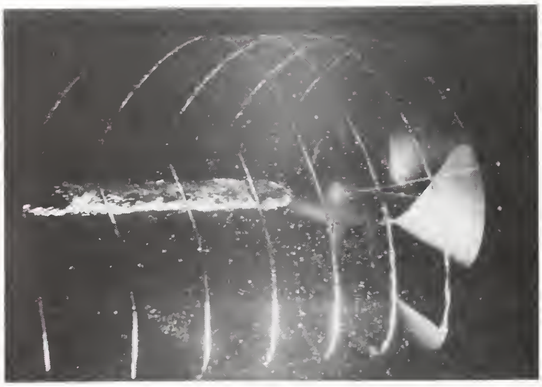
The meteorological program emphasizes the marine environment, including the marine planetary boundary layer and the development of improved forecasts for the three or four storms each winter that unexpectedly intensify to severe gales within 24 hours. A small program concentrates on the evolution of marine clouds. A new program will seek to develop better forecast tracks for tropical hurricanes.

Research in the geophysical sciences includes marine geology and geophysics, underwater acoustics and optics, and a multidisciplinary program in the Arctic. Again the emphasis is on the development of improved predictive models with major advances usually dependent on the development of new instruments and new techniques, such as remote sensing.

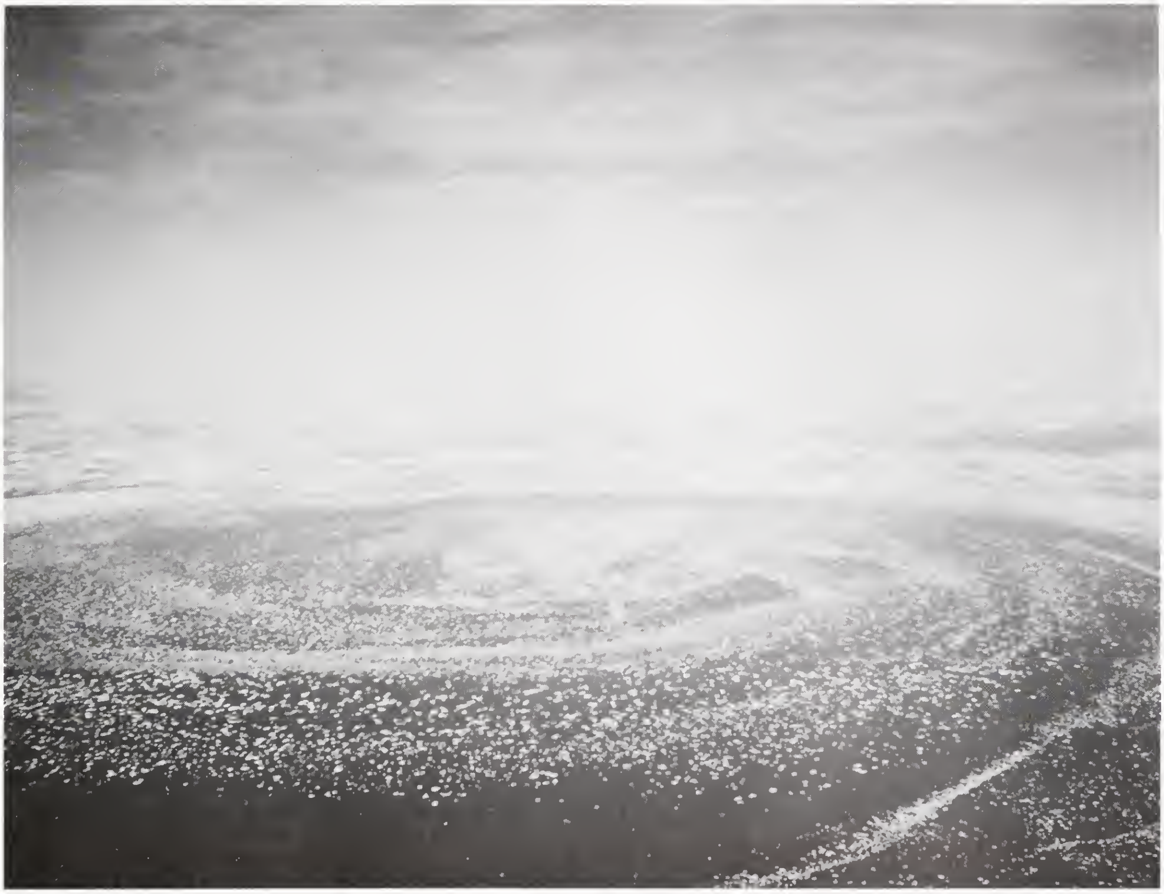
In marine geology and geophysics, our emphasis is on understanding low-frequency acoustic and seismic propagation in the marine sediments and the ocean lithosphere. This includes lateral and vertical measurements of the compressional and shear velocity using ocean bottom seismographs/hydrophones, towed arrays, and borehole sensors. To extrapolate these field measurements to other areas, the concepts of sea-floor spreading are validated using magnetic, altimeter, and gravity techniques. Sea-floor morphology is studied using multibeam echo sounders on academic research vessels equipped by ONR and by studying the effects of high-velocity bottom currents controlling bottom sediment formations.

In underwater acoustics, there are two basic thrusts—quantifying the fundamental limitations imposed by the ocean on the use of underwater acoustics, and the search for new or improved acoustic systems techniques. Both seek to improve the Navy's antisubmarine warfare capability. In the first area are programs in ambient noise, propagation through random media, volume reverberation, coherent surface scattering, inverse methods, and acoustic tomography. In the second area are studies of the turbulent boundary layer, new transducer systems for active target classification or high power, and sensors for high-speed vehicles. A new thrust will tackle the shallow water acoustic prediction problem in both a deterministic and statistical approach.

Researchers in ocean optics are developing improved models for optical attenuation in surface waters. They conduct field experiments that combine knowledge of wave forcing to provide nutrients from below and insolation causing phytoplankton blooms that define light properties as



*Research in propeller hydrodynamics. Lasers are used to test hub and tip cavatation. (U.S. Navy photo)*



*This cyclonic eddy was photographed during the 1984 Marginal Ice Zone Experiment (MIZEX). The center of the eddy was located at approximately 78°40′N and 2°W. Remote sensing instruments as well as in situ observations indicated this eddy had a lifetime of approximately 30 days. The diameter of the eddy is 30 to 40 kilometers. The convergence of the ice floes (50 to 700 meters in diameter) in the center of the eddy suggests that geostrophic effects are important. (Photo by Dr. R. A. Schuchman, Radar Science Laboratory, Environmental Research Institute of Michigan.)*

a function of depth and position. This leads to more light and a stabilized density gradient until the phytoplankton are grazed off or wave forcing brings up more nutrients from below.

Research in the Arctic is focused on developing a complete understanding of that environment. ONR interest originated with the use by the Soviets of the marginal ice zone (MIZ) as an operating area for their large strategic submarines. We need to learn more about the sea ice and oceanographic processes in the MIZ. These include the effects of waves, the atmosphere, ocean currents, and thermal stresses on the ice and on ambient noise in the MIZ. Data gathered during MIZEX (MIZ experiment), a recent extensive 2-year international measurement program, should give answers to many questions about the MIZ (see *Oceanus*, Vol. 26, No. 2, p. 55).

**Engineering Sciences**

Engineering sciences, ranging from materials to mechanics and computer science, are researched by the Navy for diverse applications.

Scientists are in search of special metal alloys, for instance, that will add strength to sea and air structures. Others work to understand how microstructure affects such alloys, which might be used to develop high-strength aircraft landing gear, lightweight wings, and aircraft support structures. Still others seek to improve the magnetic properties of materials. A recent development in this area now allows motor transformers, like those used in torpedoes, to last longer.

The art of welding is of paramount importance to the Navy, since it is the principal method of fabrication for ship structures. As a result of recent research, laser welding may find renewed competition from standard gas tungsten arc welding.

Materials research in tribology (understanding the effects of friction and lubrication) has led to ion implantation, chemical and organic lubrication compounds, and laser annealing. Researchers at the

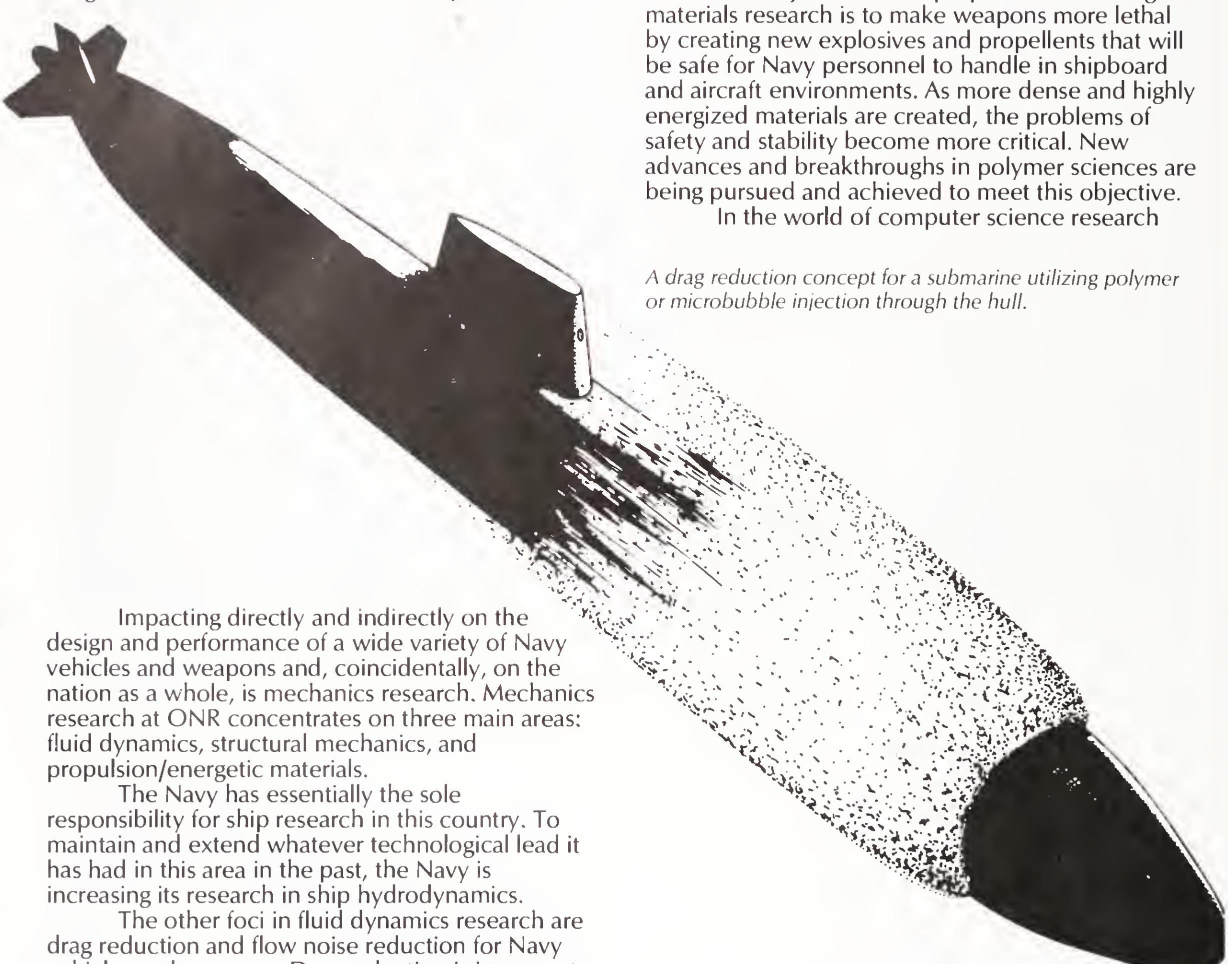
Massachussetts Institute of Technology are working on a "thin film process" that may advance the science of tribology significantly.

Ceramics and glasses are among other solid materials being studied, including the area of solid dielectrics. At The Pennyslvania State University, researchers are developing highly reliable components that will work continuously without error in such critically sensitive systems as missiles and hydrophones. Such research may lead to smaller integrated circuits and more reliable capacitors.

We are principally concerned with two areas in solid mechanics research. The first is the problem of dynamic buckling of underwater pressure hulls due to operations at deep depths and to underwater explosions. The other concern deals with reducing the signature of submersibles caused by radiated sound generated by hull vibrations. Fundamental structural dynamics research, coupled with new advances in materials science, is being applied to this sensitive area.

The objective of the propulsion and energetic materials research is to make weapons more lethal by creating new explosives and propellents that will be safe for Navy personnel to handle in shipboard and aircraft environments. As more dense and highly energized materials are created, the problems of safety and stability become more critical. New advances and breakthroughs in polymer sciences are being pursued and achieved to meet this objective.

In the world of computer science research



*A drag reduction concept for a submarine utilizing polymer or microbubble injection through the hull.*

Impacting directly and indirectly on the design and performance of a wide variety of Navy vehicles and weapons and, coincidentally, on the nation as a whole, is mechanics research. Mechanics research at ONR concentrates on three main areas: fluid dynamics, structural mechanics, and propulsion/energetic materials.

The Navy has essentially the sole responsibility for ship research in this country. To maintain and extend whatever technological lead it has had in this area in the past, the Navy is increasing its research in ship hydrodynamics.

The other foci in fluid dynamics research are drag reduction and flow noise reduction for Navy vehicles and weapons. Drag reduction is important to increase the speed of platforms both to increase their offensive capabilities and to enhance their ability to survive attack through evasive measures.

Self-generated flow noise both limits the performance of our acoustics sensors and increases our detectability by hostile sensors. Therefore, it is critical to eliminate or reduce the sources of self-induced, flow-generated noise.

In drag reduction, we have fundamental research in dilute polymer and microbubble injection into turbulent boundary layers near the surface of ships, submarines, and torpedoes. This technique reduces turbulent skin friction drag and thus permits higher speeds at the same power output. Related techniques are equally effective for suppression of self-generated noise.

some 30 years ago, ONR led the nation in computer development and since then has contributed significantly to the computer's further advancement. Today, software is critical to virtually all naval systems. It defines system capabilities, provides control ("intelligence") and the flexibility to respond to changing threats and requirements. Because of its importance, software has been identified by the Defense Science Board as a technology most likely to provide dramatic improvement in future weapons systems.

National security is dependent on information gathering. Our Artificial Intelligence Program is

## *New Navy Thrusts in Oceanography*

*Oceanography as a whole is receiving special attention at high Navy management levels. For example, Secretary of the Navy John Lehman said last year that "because of the explosive growth in research and exploration in the world's oceans, and the rapidly increasing dependence of U.S. national security on the seas . . . it is now time for a major reinvigoration of Navy efforts in oceanography."*

*Admiral J. D. Watkins, USN, Chief of Naval Operations, also signed an "Oceanography Policy Statement" stating that the ocean, as the Navy's unique operating environment, "must be measured, studied and understood," and that the Navy should "provide increasing support to the most promising initiatives" in ocean science.*

*Secretary Lehman defined a 15-point program with two major thrusts to execute his "reinvigoration" concept. The first affects academic research oceanography and includes research funding increases, establishing Navy research chairs in oceanography at selected universities, increased Navy graduate research fellowships, increased use of naval deep submergence assets, such as the 6,000 meter depth capability of Sea Cliff by academia, the construction of a major new academic research vessel, and development of a long-range replacement plan for construction of research vessels.*

*The second thrust is to strengthen the utilization of oceanographic knowledge in naval weapon systems procurement and to upgrade the quality of oceanographic predictions provided to the fleet. This includes strengthening the career path and training support for oceanographers designated naval officers, establishing an Institute of Naval Oceanography with a focus on ocean modeling, and enhancing the position of the Oceanographer of the Navy with a direct reporting chain to the Chief of Naval Operations.*

*The new oceanographic research vessel to be used by the civilian academic research community has a target completion date of 1991. This major floating research lab will have the speed and endurance to meet worldwide ocean research and data collection requirements year-round. It will be a state-of-the-art ship capable of operating in moderately high seas. It will berth about 30 scientists, and have combined deck and laboratory space of more than 7,500 square feet. While both SWATH (Small Waterplane Area Twin Hull) and monohull designs are proposed, serious consideration is being given to building a large SWATH vessel.*

*The Navy is also actively involved in demonstrating how manned space flight can advance knowledge of the ocean. Paul Scully-Powers, a civilian oceanographer with the Naval Underwater Systems Center, flew onboard space shuttle mission 41C in October, 1984. This was viewed by the Navy as a major opportunity to be shared by both the Navy and civilian oceanographic research communities* *(see page 84).*

*Importantly, this flight demonstrated the role of manned space flight in advancing our knowledge of the ocean, while also emphasizing the need for an ocean satellite system. Taken together, manned space activity in oceanography and existing environmental satellites complement each other in important ways. Our space oceanography efforts are continually giving us new insights into the complex nature of the ocean* *(see page 22).*

*Our space oceanographic efforts are revolutionizing ocean science for both the civilian and Navy research communities and serve to demonstrate the importance of the Navy's role in space to exploit our unique operating environment to strategic and tactical advantage.*

**—JBM**

developing computerized natural language techniques for summarizing narratives, such as newspaper reports. These can be helpful in detecting patterns either within individual documents or through an accumulation of documents gathered over time. The ability to detect such patterns in great masses of documents is important to intelligence techniques.

An artificial intelligence system known as an expert system can provide advice and problem solving skills relative to military decision making, crisis alerting, and maintenance of weapon systems. Basic research is being done to expand on such a system's capabilities. It is likely that in the future, military decision making will have to be supported by networks of many such expert systems working cooperatively. Our objective in this area is to determine how to design expert systems that will function well in such a dispersed environment.

Basic research intended to improve the expert system and natural language system capabilities mentioned previously is directed at the fundamental issues of knowledge representation and automated reasoning. Research in knowledge representation seeks to determine how best to express and organize information within the computer. Research in

automated reasoning seeks to determine how that information can be manipulated in order to both duplicate and extend human capabilities for deductive reasoning, inductive reasoning, reasoning by analogy, and common sense.

Progress in producing intelligent aids to human decision making will lead to designing intelligent robots. Such robots with autonomous capabilities for reasoning and navigation and manipulation have the potential to be deployed in almost any environment. Specific missions related to national security could include surveillance, search, and recovery.

**Life Sciences**

As the Navy becomes more dependent on high technology, its men and women will perform within increasingly complex and challenging environments. One research focal point is on computer-assisted instruction to make the Navy's training programs more efficient and effective.

Tactical decision-making research is a program designed to develop scientific models to measure decision-making effectiveness in command control environments where one set of decisions impact on a complex array of other problems, related to such elements as space, resources, and information.

On the biological scene, through a special immunological defense program, researchers hope to learn how to enhance the response of the immune system. Such natural biological defenses are needed to protect Navy and Marine Corps personnel against agents that may be used in chemical or biological warfare, natural infectious agents, toxins, and other noxious materials that may be encountered in operational environments.

Related research is studying the complex interactions between the brain and the immune system to understand how environmental and emotional stresses affect the health and performance of not just Navy and Marine Corps personnel but everyone in general.

**Educating Scientists and Engineers**

As the last half of the 1980s approaches, the Navy's research and development momentum is increasing in the face of Soviet developments. But caution should remain the order of the day. The U.S. qualitative advantage should not be taken lightly. Needs remain to produce not only the best technological Navy in the world, but to provide the means to develop new legions of young scientists to join and follow after those who have made the U.S. Navy second to none.

ONR strives to enhance scientific development in several ways, in addition to direct university research support. Following are ONR-supported programs that tie the Navy's R&D efforts to academia and directly or indirectly contribute to the development of scientists and engineers:

***Navy Science Awards Program:*** High school students across the nation who exhibit projects at regional and state science and engineering fairs are eligible to compete for Navy-sponsored college scholarships ranging from $1,000 to $10,000 as well as other awards, including trips to Navy laboratories and to an international science-oriented gathering in London.

***ONR Young Investigator Program:*** This new program supports young independent academic researchers who received their Ph.D.s (or equivalent) after January 1, 1980. The basic research support award is $50,000 a year for three years with the possibility of greater support through matching funds.

***U.S. Navy Summer Faculty Research Program:*** Science and engineering faculty members from U.S. universities spend 10 weeks at Navy research and development centers working with professional peers on research tasks of mutual interest.

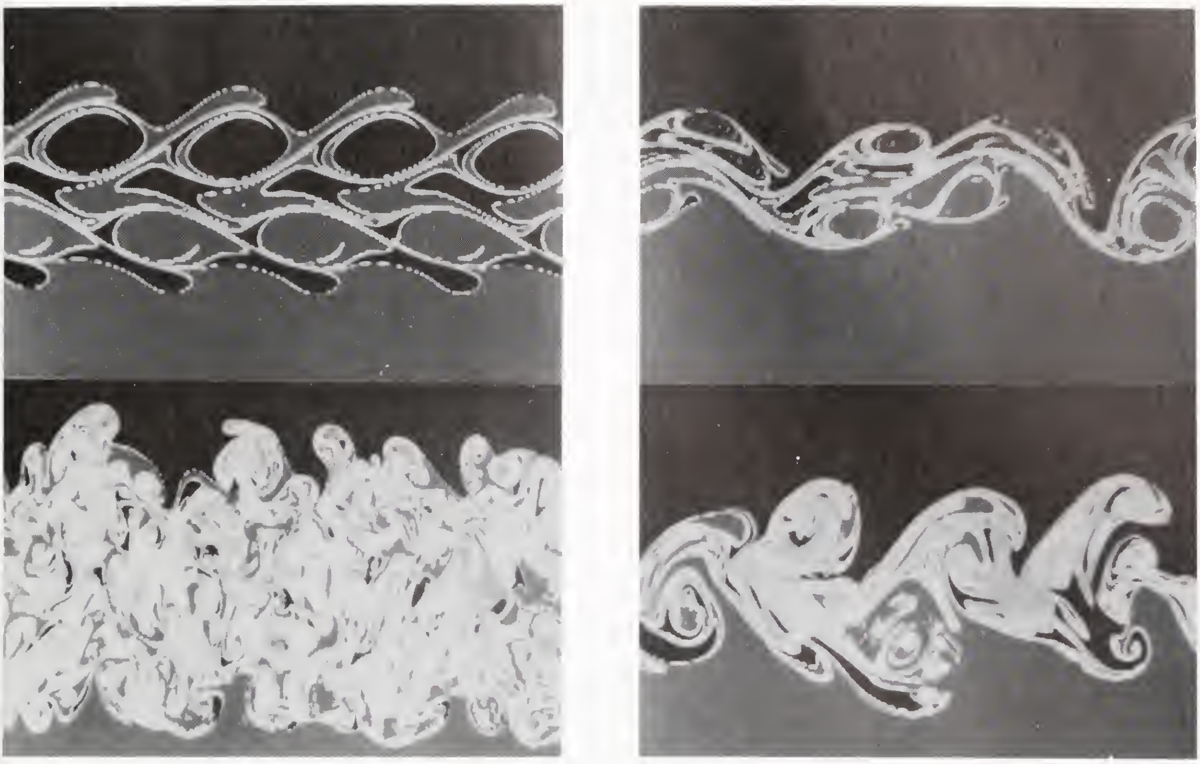
***ONR Graduate Fellowship Program:*** The purpose of this program is to increase the supply of Ph.D.-trained U.S. citizens in disciplines of science and engineering critical to the Navy. In particular, this program increases the pool of scientists and engineers available for potential employment by Navy laboratories. At present, ONR is supporting 106 fellows in nine disciplines. Each fellowship is awarded for three years.

***ONR "Bridges" Program:*** This new program involves senior university faculty and their graduate students in research activities of interest and importance to Navy labs in areas of strong national interest. It provides a structured setting to encourage cooperation among ONR contractors and the labs.

***SECNAV Research Chairs in Oceanography:*** The Navy expects this year to create oceanography chairs at three universities to stimulate and broaden the oceanography scientific pool and strengthen and retain the best scientists to work on Navy problems. Up to now, the only chairs in support of Navy oceanographic research have been two at the Naval Postgraduate School (Arctic Science and Underwater Acoustics) and one at the U.S. Naval Academy (Remote Sensing).

***Selected Research Opportunities (SRO) Program:*** The SRO Program is designed to improve national defense over the long term by involving the academic research community in selected fundamental research areas, and by fostering stronger linkages between this community and the Navy. Contracts are awarded to universities for up to three years.

***Bunting Institute Program:*** The Mary Ingraham Bunting Institute at Radcliffe College provides opportunities for women to advance their careers in many of the humanities, arts, and sciences. ONR has for the last few years supported science scholarships there. During a one- or two-



*Flow visualization using reactant dyes to investigate the turbulent structure of disturbed and undisturbed mixing layers. (U.S. Navy photo)*

year fellowship, the science scholars work at one of the universities in the greater Boston area, often reestablishing themselves in their discipline and leading to career advancement. Sixteen Bunting Science Scholars have completed their fellowships with ONR support.

**ONR Objective: National Security**

As the scope of the nation's scientists and engineers expands through such educational programs, so expands the significance of the Office of Naval Research as a major focal point in the world for basic scientific research. ONR enhances U.S. national security in its broadest, most comprehensive sense. That enhancement translates to strength in the national economy, international commerce, and military defense through advancements in mathematical modeling, through improvements in materials and engineering evolution, and through better understanding of communications and the environments that surround us.

Science and technology provide the ideas and the hardware that make these strengths renewable and capable of sustaining national security. ONR continues to work at building technologies necessary to maintain and protect our national security well into the next century and beyond.

*Rear Admiral J. B. Mooney, Jr., is the 15th naval officer to be designated Chief of Naval Research, a Presidential appointment. Formerly Oceanographer of the Navy, he holds the distinction of being the fifth person to qualify as a Hydronaut (Deep Submergence Vehicle Operator) in the Navy. He was at the controls of the* Trieste II *when, in 1964, it located the hull of the sunken submarine* U.S.S. Thresher *on the floor of the Atlantic at a depth of 8,500 feet. In 1980, he completed an Executive Program in National and International Security at Harvard University.*

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*The Vanguard I satellite rises from the first complete satellite-launching facility at Cape Canaveral. (U.S. Navy photo)*

# The Navy's Mission in Space

**by Peter A. Mitchell**

The U.S. Navy's present missions—sea control, projection of U.S. power worldwide, establishment of a political presence through deployment of the fleet, and strategic deterrence—are essential to our national security. To support such global commitments requires that our ships and submarines be able to navigate throughout the world. Similarly, control of a global navy requires secure, reliable communications. Today, the U.S. Navy relies on navigational and communications satellites to provide these essential services.

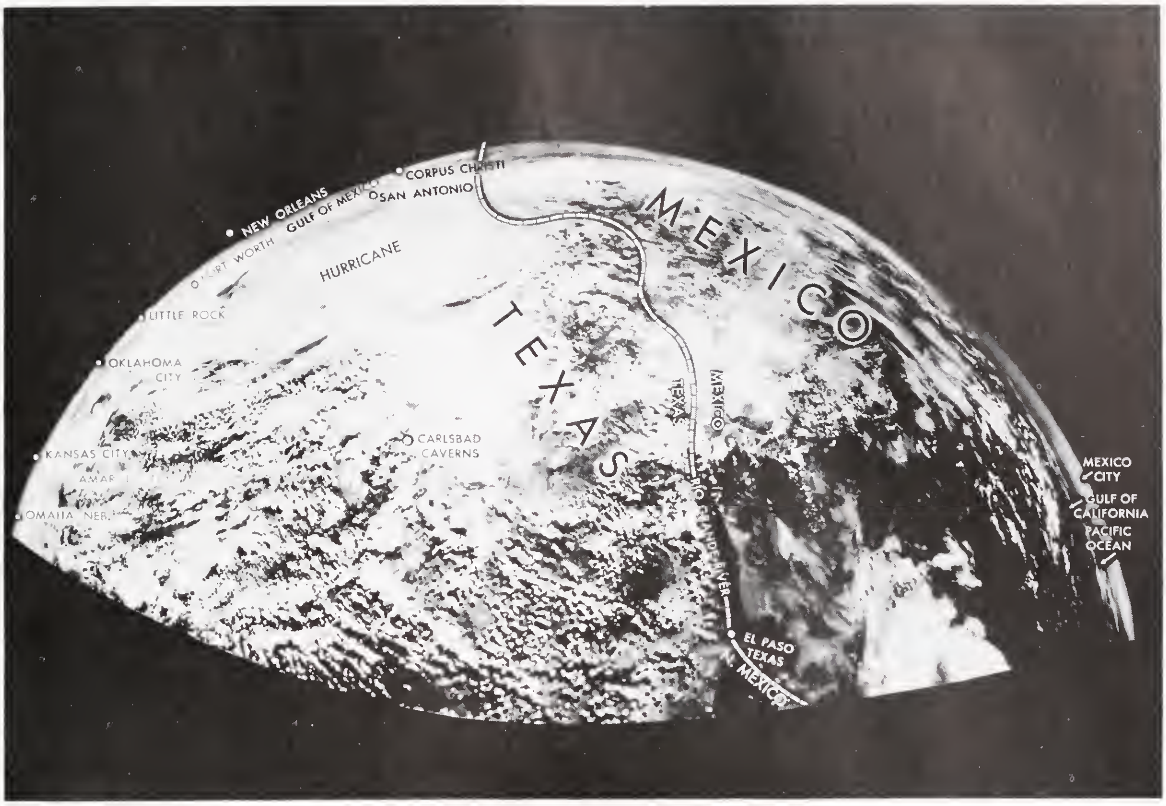
Perhaps still more importantly, we are in an age of rapid technological advances in weapon systems, tactics, and detection of the enemy. To make effective use of these sophisticated technologies and at the same time nurture strong research and development programs, knowledge of the environment becomes increasingly important in all aspects of naval operations. This knowledge is being provided largely by satellites.

The nucleus of this age of electronic navigation, communication, and sensing of the environment was created in the late 1940s and 1950s by the U.S. Navy.

**Early Efforts**

In October of 1955, the U.S. Navy, through its Naval Research Laboratory (NRL) in Washington, D.C., was delegated the responsibility to build, launch, and place into Earth-orbit an artificial satellite carrying a scientific experiment. The program was dubbed Project Vanguard, and was a continuation of an NRL program started after World War II that used instrumented German V-2 rockets to probe high into the Earth's upper atmosphere.

As the supply of V-2 rockets dwindled, NRL began development of a new, large, liquid-propelled rocket, the Viking. Twelve Vikings were launched by NRL between 1949 and 1954, establishing many milestones: first measurements of temperature, pressure, and winds in the upper atmosphere; first measurements of the electron density in the ionosphere; first records of the ultraviolet spectra of the sun; and first high-altitude (approximately 100




*The first high-altitude picture of a hurricane was taken in October of 1954 from an NRL Viking rocket. Although shown here in black and white, this was the first color photograph successfully taken from such altitudes, and initiated the interest of the weather service in high-altitude weather reconnaissance. (U.S. Navy photo)*

miles) photographs of the Earth (in both black and white and color).

After the Naval Research Laboratory was selected for Project Vanguard, the laboratory, with the aid of a contractor, began development of a 3-stage launch vehicle patterned after its successful Viking rocket. This new series of rocket later became the basis for the design and fabrication of such launch vehicles as the reliable Delta series, which was used extensively by the National Aeronautics and Space Administration (NASA) for many communication, meteorological, and scientific satellites. With no suitable satellite launching facilities available, NRL constructed the first complete facility at Cape Canaveral, Florida. Since a suitable satellite tracking system did not exist, NRL developed the world's first satellite-tracking system (called "Minitrack") in 1956.

The Vanguard-I satellite was successfully launched into Earth orbit on March 17, 1958. Although it was not the first U.S. satellite successfully launched (the Explorer satellite was placed into orbit on January 31, 1958), Vanguard-I attained the highest altitude of any man-made vehicle to that time. It still orbits the Earth today and will remain in orbit well into the 22nd century. Soon after launch of Vanguard-I, NASA was created (July 1958) and Project Vanguard along with some of its personnel was transferred to the new agency. The project became the core of NASA's space flight activities.

Vanguard-II was placed into orbit on February 17, 1959, and was the first satellite designed to observe and record the cloud cover of the Earth. As such Vanguard II was the forerunner of future meteorological satellites. Vanguard-III, the last of this series, was successfully placed into Earth orbit on September 18, 1959.

Sufficient personnel from Project Vanguard remained at NRL to develop a naval satellite program. This program grew throughout the 1960s, 1970s, and 1980s, and developed navigational and environmental satellites for scientific purposes, military intelligence, and to assist with the Navy's operations.

**Navigational Satellites**

Modern navigation is said to have started with the three epic voyages of Captain James Cook to the Pacific Ocean between 1768 and 1799. With the first reliable chronometers (time pieces designed to keep time with great accuracy), nautical almanacs, adequate charts and map projections, and the first reliable compasses (along with an understanding of magnetic variation), Cook and his contemporaries were able to accurately determine their latitude and longitude and fix their position on the high seas.

The next great leap in the field of navigation came with the application of electronics. In 1904, the transmission of radio time signals permitted the mariner to check his chronometer at sea. Radio broadcasts, beginning in 1907, provided navigational warnings of foul weather, icebergs in northern

shipping lanes, and submerged hazards. During the decade prior to World War II, work on early television and cosmic counting devices allowed the development of radio aids to navigation based on the time of transmission of radio signals from three or four different transmitting stations. If these signals are closely synchronized, the difference in transmission times would establish a position fix. This work in turn led to the development of the radio navigation systems in use today such as Loran-C, Omega, and the Decca Navigation Systems, which provide reliable reception at distances ranging from 300 to 1,200 miles.

With the arrival of the space age, it became possible to provide an accurate worldwide navigation system for all naval surface vessels, aircraft, and submarines. Scientists at the Applied Physics Laboratory (APL) of Johns Hopkins University discovered the fundamental concept of such a system when they were monitoring the beeps being transmitted by the Soviet Union's Sputnik I in 1957. As they monitored Sputnik's signals, the scientists found that the change in the signals' frequency as the satellite moved toward or away from them (Doppler effect) could be used to describe the satellite's orbit. They then concluded that, inversely, if the satellite's orbit was well known, the Doppler effect could be used to determine one's position on Earth. Based on APL's work, in April 1960 a prototype navigation satellite was successfully launched and demonstrated its operational potential by providing navigational fixes to within a quarter of a mile. A second prototype satellite was launched in June of 1960.

By the beginning of 1964, a complete satellite navigation system, known as the Navy Navigation Satellite System (NAVSAT) or Transit, was providing Navy operators with global two-dimensional positional information with an accuracy of better than a tenth of a nautical mile. Conception and development of the Transit System were orchestrated by the APL, but the daily operation of the system was placed under the control of the U.S. Navy Astronautics Group located at Point Mugu, California. The Transit System was developed by the Navy primarily to provide accurate position information for its Polaris submarine forces.

Today, the Transit system consists of a constellation of polar-orbiting satellites (a minimum of four satellites is needed for system operation) at altitudes of between 450 and 700 nautical miles; it still meets its objective of providing continuous global coverage under all weather conditions to both U.S. ballistic missile submarines and naval surface ships. Many foreign countries, especially those of the North Atlantic Treaty Organization (NATO), use Transit information for the navigation of their military forces. Other U.S. government agencies, such as the Defense Mapping Agency, use this information for precise geodetic surveying.

In 1967, the Navy released information to the public about the satellite message parameters, procedures needed to calculate a position, and the detailed technical specifications needed for the fabrication of a receiver capable of obtaining data from the Transit satellites, opening this global navigation system (at the time, the only one in existence) to the worldwide maritime community. Since then, the interest of the private and commercial sectors in the system has grown substantially. Non-military users of the Transit system include: commercial fishing vessels, private pleasure vessels, commercial shipping companies, offshore oil drilling companies, and oceanographic and hydrographic (dedicated to charting waters) research vessels.

Time has been important in navigation from the earliest chronometer design to the present. To improve the accuracy of the data from satellite navigation systems, NRL embarked on a program in 1964 to develop high-precision timing devices necessary for use with a passive ranging system. The project was called TIMATION, for TIMe navigATION, and was an outgrowth of the Applied Physics Laboratory's effort to develop practical methods to track satellites by measuring distances through the use of synchronized receivers and transmitters. The first satellite of the program (Timation-I) was launched by NRL in May of 1967 and demonstrated that a surface vessel could be positioned to within two-tenths of a nautical mile and an aircraft to within three-tenths of a nautical mile using range measurements from a time-synchronized satellite. Timation-II, featuring a two-frequency ranging system (to compensate for the bending of radio waves as they pass through the ionosphere) and an improved clock, was launched two years later into a nearly identical orbit. Results from these two experiments led to further improvements in satellite timing devices and demonstrated that it might be possible to design a satellite system that could give positions continuously in three dimensions using range measurements. NRL's Timation program was merged in 1973 with a U.S. Air Force project that was investigating similar techniques.

From this merger, the NAVSTAR or Global Positioning System (GPS) Project was created; it will eventually replace the Transit system. From 1978 through 1984 several prototype NAVSTAR/GPS navigation satellites have been placed into orbit (at this writing there are five) for concept validation testing and have demonstrated that a passive radio-navigation system can provide very accurate positional and time information continuously in three dimensions on a global basis.

When fully operational at the end of this decade, NAVSTAR/GPS will consist of an 18-satellite constellation, and its primary objective (as with the Transit system) will be to support the Navy's Fleet Ballistic Missile Program. The user community will again include civilian as well as military users, but data available only to the military will allow much more precise positional information.

The GPS system is being developed by a joint management team whose members include personnel from the Navy, Air Force, Army, Defense Mapping Agency, Department of Transportation, and the North Atlantic Treaty Organization. It is currently planned that GPS will be operational for five years before Transit is entirely phased out in the mid-1990s.

## Communications Satellites

With segments of our naval fleet located in all the major oceans of the world, communication links are essential not only for day-to-day operations but also to insure a quick response during international crises. Since its very beginning in 1923, NRL has conducted the Navy's principal in-house research program in radio communication. The programs and achievements attained at NRL in the areas of very low frequency (VLF), high frequency (HF), very high frequency (VHF), ultra high frequency (UHF), and super high frequency communications (SHF) are too numerous to list here; however, the Navy also has conducted pioneering work in satellite communication.

During the 1920s, the Naval Research Laboratory determined the frequency above which radio waves could penetrate the Earth's atmosphere and propagate through the vacuum of space. It was not until 1949, however, that NRL demonstrated that radio signals originating on Earth could be beamed into space and returned from an orbiting satellite. At that point in time the only orbiting satellite available for this feat was the one that has always brightened the night sky, the moon. In July of 1954, NRL accomplished the first round-trip transmission of a human voice to the moon and back. This was quickly followed by the first demonstration by NRL of transcontinental and transoceanic satellite communication (via the moon) in 1955 and 1956, respectively. In January of 1960, the Navy publicly demonstrated the world's first operational satellite communication system when messages were exchanged between the Chief of Naval Operations in Washington, D.C., and the Commander-In-Chief of the Pacific Fleet at Oahu, Hawaii, through the moon relay system. The first transmission of pictures via this system also was demonstrated at that time. With the launch of the ECHO-I satellite (a 100-foot-diameter, aluminum-coated, plastic sphere) in August of 1960, the Navy showed that communication signals could be relayed through a passive, Earth-orbiting satellite. Further work on the moon relay communication program demonstrated the feasibility of one-way shore-to-ship communication in 1961, and two-way communication in 1962, thereby establishing the first operational worldwide satellite communication system.

In parallel with work on its moon relay communications program, the Navy, through NRL, proposed a research and development program directed at using satellites acting as transponders* to relay communications over long distances. A joint Navy, NASA, and Army project was established to develop this technology in 1962. NASA developed the satellite, the Army provided the ground terminals, and the Navy supplied a ship equipped with an experimental ship terminal. Using NASA's SYNCOM-I (Synchronous Communication) satellite, which was launched in February 1963, a Navy ship (*U.S.S. Kingsport*) became the first ship to transmit and receive a voice message via an active satellite. A total of three SYNCOM satellites was launched in 1963 and 1964; they were used extensively (along with later satellites developed by the Air Force) by the Navy to develop the necessary operational equipment (antennas, shipboard and ground satellite terminals, and so on) and to insure that communication satellites being developed would be adequate to meet the Navy's operational requirements.

Today, space-based, naval communication systems permit the automatic transmission of naval communications worldwide (between the latitudes of 70 degrees North and 70 degrees South) via an extensive array of satellites. The Navy Satellite Communication (SATCOM) System provides communication links between surface ships, submarines, aircraft, and the shore. In 1976, three communication satellites were placed into geo-synchronous* orbit over the Atlantic, Pacific, and Indian Oceans. These satellites, called GAPFILLER by the Navy, were procured and are managed by the Communication Satellite General Corporation (COMSAT). The Navy has leased three UHF channels on these satellites through 1985. A second operational communication satellite system is also in use with four satellites in geo-synchronous orbit over the continental United States and the Atlantic, Pacific, and Indian Oceans. This second system is known as the Fleet Satellite Communication (FLTSATCOM) System.

The next generation of communication satellites to be used by the Navy will also be on a leased basis. This system is known as LEASAT and will serve as a replacement for the GAPFILLER satellites currently in orbit. In August and November of 1984, the first two of a planned system of four LEASAT satellites were placed into orbit from the space shuttle and are presently undergoing testing. The remaining two satellites will be in place by 1986.

## Environmental Satellites

The ships and aircraft of our modern naval forces travel through an ocean of air and on a sea of water. Their travel and the tactics used are greatly influenced by the ever-changing natures of the ocean and atmosphere. Knowledge of the environment in which our fleet operates never before has been so vital to the fleet's safety and choice of operating tactics. Amphibious and antisubmarine warfare, search and rescue, and salvage operations particularly benefit from this knowledge.

Navy operations require, as a minimum: tactical weather forecasts for ship-routing and aircraft operations; forecasts of sound propagation

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* Transponders receive a signal and then retransmit it to another transponder or the final receiving station. Since it is constantly being renewed, the signal can remain quite strong over long distances. Satellites functioning as transponders are called active satellites.

* In a geo-synchronous or geo-stationary orbit, a satellite revolves around the Earth in the same direction as the Earth's rotation once each day. Thus a satellite in such an orbit appears to remain stationary above a single point on the Earth.

parameters for antisubmarine warfare; forecasts of tides, waves, and currents for mine laying and sweeping operations, as well as for search and rescue missions; and ice forecasts for both surface and subsurface navigation.

Immediately after World War II, naval warfare technologies (developed out of necessity to defeat two strong enemies) were rapidly improved. Soon very complex surface and subsurface weapon systems, sensors, platforms, and corresponding tactics* were added to the Navy's arsenal. For these, new hardware and tactics to perform their tasks effectively, whether located in relatively shallow coastal waters, in the deepest ocean basins, or on or within ice-covered polar waters, accurate and immediate knowledge of the environment is needed. The Navy also recognized the need of the platform and weapon systems designers for a clear understanding of the environmental parameters that affect the performance of their creations.

With the increasing use of aircraft in naval operations, it became possible for the naval tactician to expand his knowledge of the environment, from that small portion which could be seen from a ship's bridge or measured by instruments lowered over the side, to very broad expanses of the ocean. It also meant that the mariner needed information not only concerning the state of the surrounding ocean but also concerning the state of the atmosphere in his operating area. As with the technologies developed in spaceborne navigation and communication satellites, many of the advances in instrumentation made in airborne remote sensing were refined and applied to sensors on satellites. These satellites extend the mariner's vision to encompass entire oceans (Table 1).

The value of imagery from space was evident from the first photographs taken at high altitudes by cameras on the Navy's Viking rockets in the early 1950s. The first environmental satellite (TIROS-I), with television and infrared sensors on board, was placed into Earth orbit in April 1960 by NASA for the National Weather Service. This meterological satellite returned to Earth images of constantly changing cloud and storm systems, ice moving through the Gulf of St. Lawrence, and of snow accumulation. When it was demonstrated from these early images that the white tones of clouds could be distinguished from those of snow and ice, the science of spaceborne oceanography was born. This fledgling science was further nourished when astronauts on board the Project Mercury and Gemini missions returned to Earth with photographs showing never before seen perspectives of extensive areas of the world's oceans. (At this point we cannot discuss the Navy's role in space without a mention of the fact that the first American in space, Captain Alan B. Shepard, Jr., was a naval aviator.)

Even before spaceborne oceanography became a reality, physical oceanographers proved the importance to naval operations and tactics of environmental parameters, such as sea-surface and subsurface temperature gradients, winds, sea states, currents, oceanic fronts and eddies, and the location and extent of sea ice.

With no dedicated spacecraft of its own during the early years of satellite oceanography, the Navy exploited the ocean measurements made by both experimental and operational global weather satellites developed by NASA and the National Weather Service, respectively. Even though measurements of oceanic data were not the primary objective of these satellite missions (meteorological measurements were paramount), valuable information was received and used for operational missions, and research and development. With the development and testing of sensors operating outside the visible portions of the spectrum and extending into the infrared, a whole new way of looking at the oceans emerged and became standard equipment on subsequent environmental satellites.

Other satellites in the TIROS series and the ESSA I and II satellites were launched between 1963 and 1966. These carried uncalibrated, low-resolution, visible and infrared detection systems. Data from these systems were used by Navy sea ice forecasters to improve and verify their forecasts. These satellites enabled the relay of information concerning the location, extent, and movement of sea ice to Coast Guard ice breakers and resupply ships navigating in the Arctic and Antarctic.

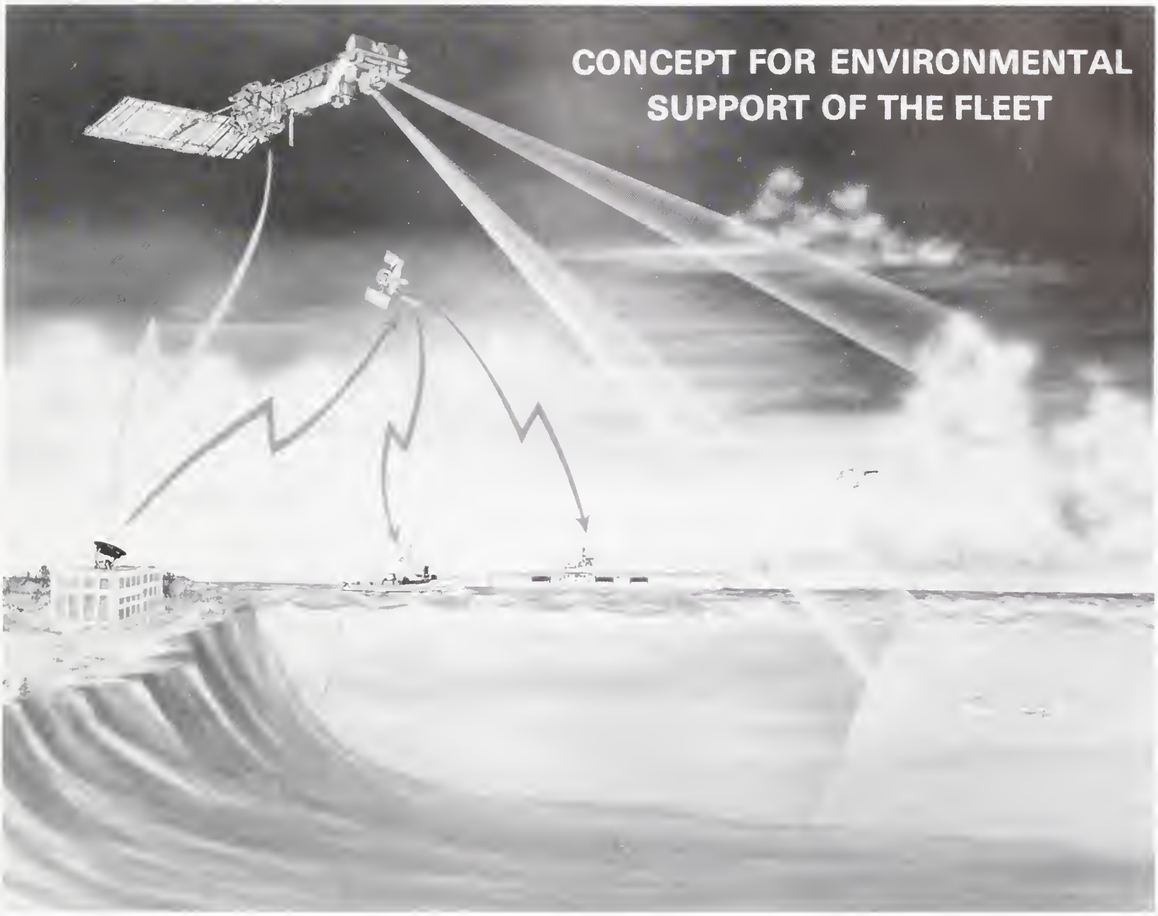
The next generation of environmental satellites was developed in the early 1970s and included the Improved TIROS Operational Satellites (ITOS) and the Defense Meteorological Satellite Program (DMSP). The rudimentary sensors of the previous generation were replaced by calibrated, scanning, high-resolution radiometers. It then became feasible for the naval oceanographer to process the infrared data differently from the meteorologist and make quantative measurements of sea-surface temperatures. With these new measurements, it became possible to delineate thermal patterns on the ocean surface that were characteristic of oceanic fronts and eddies—

**Table 1. Operational and experimental satellites used by the U.S. Navy for ocean monitoring.**

| Satellite | Period of operation | Type |
|---|---|---|
| TIROS 1–10 | 1960–66 | Experimental |
| ESSA 1–9 | 1966–76 | Operational |
| ITOS 1 | 1970–71 | Operational |
| NOAA 1–9 | 1971–Present | Operational |
| TIROS N | 1978–81 | Operational |
| NIMBUS 1–7 | 1964–Present | Experimental |
| *ATS 1 & 3 | 1967–74 | Experimental |
| *SMS 1–2 | 1974–81 | Operational |
| GOES 1–6 | 1976–Present | Operational |
| GEOS 3 | 1975–79 | Experimental |
| LANDSAT 1 | 1972–77 | Experimental |
| LANDSAT 2–5 | 1975–Present | Operational |
| SKYLAB | 1973–74 | Experimental |
| DMSP | 1972–Present | Operational |
| SEASAT | 1978 (3 months) | Experimental |
| GEOSAT | 1985 & beyond | Operational |

* Geo-stationary

* Weapon systems actually launch and deliver explosives to enemy targets; they include guns, missiles and missile launchers, torpedoes, and the like. Platforms carry weapon systems to the scene of battle; they include ships, submarines, and aircraft.




*Space-borne environmental sensors support many elements of U.S. naval forces.*

invaluable to the Navy researcher working on antisubmarine warfare. From this early data, mathematical models useful in antisubmarine warfare were developed and tested by collecting ground-truth data coincident with remotely sensed data.

Modern naval remote sensing programs from their inception have received a major impetus from the Office of Naval Research (ONR); even the term remote sensing was coined at ONR in the early 1960s. The first remote sensing symposium was sponsored by ONR at the University of Michigan's Willow Run Laboratories in February 1962. Since then, these yearly symposia have become international in scope, attended by hundreds of scientists from all over the globe.

In the early 1970s, ONR assumed a leadership role in spaceborne oceanography by commissioning the U.S. Naval Oceanographic Office to perform a study of coastal oceanographic processes with DMSP imagery. This study provided near real-time information on the position and structure of sea-surface temperature gradients, as well as a means of estimating temperature differences between water masses.

The DMSP program was developed by the Air Force in the early 1970s to provide weather data to its forces in Southeast Asia. It is presently a joint armed forces program that is managed by the Air Force with naval liaison officers stationed at the central DMSP sites. Its complement of environmental sensors includes a scanning visible/infrared radiometer and a vertical atmospheric temperature profiler on board two polar-orbiting satellites. The system can directly transmit data in digital form on a daily basis to tactical receiving sites, some of which are on aircraft carriers. Many others are transportable and can be deployed to U.S. Navy and Marine Corps facilities or operating areas within hours.

Through the early 1970s, the satellite sensors and systems developed had as their primary mission the study of meteorological phenomena. However, that began to change as interest in the measurement of oceanographic parameters grew in both the military and civilian commercial sectors. New sensors to concentrate on oceanic parameters were rapidly developed. For example, sensors designed to collect data in the microwave (beyond the infrared) region of the spectrum were used to measure both meteorological and oceanographic parameters. These sensors were flown between 1972 and 1975 on NASA's experimental satellites, such as NIMBUS 5 and 6. Unlike infrared radiometers, these sensors could map the ocean surface through cloud cover.

With such data, naval sea-ice forecasters could map the extent, concentration, and type of ice at the poles—despite the extensive perennial cloud cover—day or night. With the Arctic region developing into an important strategic area in this day of missile-carrying submarines, this capability became vital to our defense strategy.

These new sensors also could determine atmospheric temperature profiles and atmospheric water content. Such information is used in numerical weather forcasting models being developed for (and in use at) naval facilities, such as the Fleet Numerical Oceanography Center (FNOC) in Monterey, California.

The technologies developed for these early microwave radiometers were applied to the development of a new microwave sensor, the Scanning Multichannel Microwave Radiometer (SMMR). This sensor was added to the suite of experimental sensors of NIMBUS 7, launched in October 1978. Thus, NIMBUS 7 could measure not only the parameters mentioned above but also two very important parameters to oceanographers, sea-surface temperatures and near-surface winds.

Technology from the experimental SMMR has been applied to an operational imager soon to be flown on a DMSP satellite. This sensor, the Mission Sensor Microwave Imager (SSM/I) is being developed jointly by the Navy Space Systems Activity, the Naval Research Laboratory, and the Air Force Space Division as an all-weather oceanographic and meteorological sensor. Data from the SSM/I will be processed by the FNOC to obtain precipitation maps, sea-ice morphology, sea-surface wind speed, atmospheric liquid water, and soil moisture percentages.

In the early 1970s, a parallel program was initiated to exploit different types of microwave sensors. All of the sensors described previously are known as passive sensors: ones that measure the natural radiation emanating from the objects being observed. These new sensors were active—they would send out signals and then measure the returning signals, or echos, from the objects under investigation. The first of these sensors, a combination microwave radiometer/active radar scatterometer and active radar altimeter instrument,* was flown from May 1973 to February 1974 on the manned space station, SKYLAB, from which astronauts (two-thirds of whom were Navy Department officers) conducted the first experiments in gathering oceanic data using microwave sensors.

The radiometer/scatterometer sensor data demonstrated that passive microwave radiometric temperatures could be used to correct for the errors introduced by the intervening atmosphere and that the scatterometer backscatter measurements, after correction, could be used to determine wind speed and direction over the ocean. On SKYLAB, a second microwave radiometer verified theoretical relationships between its measurements and the oceanic parameters of salinity, surface wind, and sea-surface temperature.

Data from SKYLAB demonstrated that the Earth's geoid could be measured from spacecraft altitudes. From the data, oceanographers could infer information vital to naval tactics concerning ocean fronts, currents, and eddies. An accurate geoid is becoming increasingly vital in the targeting of ballistic missiles and in the production of accurate maps and related charts. The SKYLAB altimeter also could measure wind speed and wave heights. Although the altimeter was designed for ocean observations, scientists at NRL analyzed the signals returned from terrain features and established the altimeter's capability to characterize different types of terrain from spacecraft altitudes.

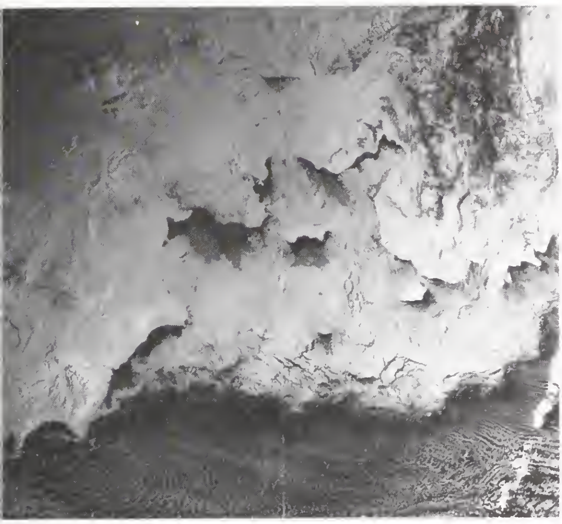
Success of this prototype altimeter led to the launch of a second altimeter on board the GEOS-3 satellite in April 1975, and produced the first extensive operational measurements of geodetic and oceanographic parameters. An improved altimeter was designed and placed into orbit on board the SEASAT satellite in June 1978. This altimeter performed its mission outstandingly by measuring distance to the Earth's surface to a precision of less than 10 centimeters. It provided global observations of sea bottom topographic features, thereby contributing to the accurate mapping of underwater features necessary for subsurface navigation. Success with the altimeters from SKYLAB, GEOS-3, and SEASAT led to a Navy altimetry mission, GEOSAT. The GEOSAT satellite was launched on March 12, 1985, and carries only one sensor—a radar altimeter. Its primary mission is to derive an accurate geoid in support of the U.S. submarine ballistic missile program. A secondary mission will be to use this data to obtain environmental information on waves, winds, currents, fronts, eddies, and sea ice, and other phenomena.

The SEASAT satellite mentioned previously was the first environmental spacecraft dedicated exclusively to the all weather measurement of oceanographic parameters by microwave sensors. Along with the altimeter, its sensor complement included a scatterometer, radiometer, and a synthetic aperture radar (SAR)* (see *Oceanus*, Vol. 24, No. 3, Oceanography from Space).

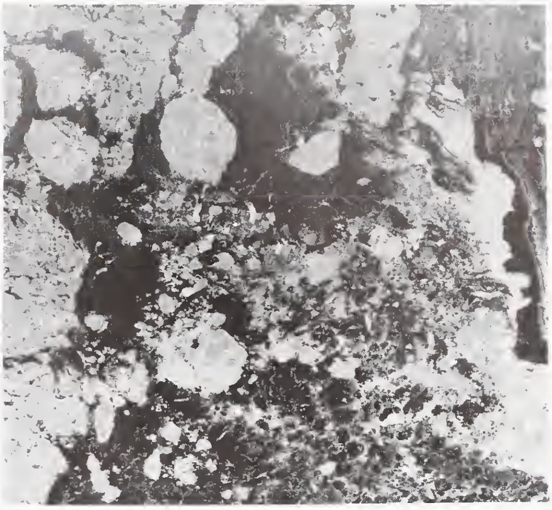
Although, as the result of a massive power failure, the SEASAT mission lasted only a little more than 100 days, all of the microwave sensors performed within specifications or better and

* A microwave radiometer measures the intensity of the electromagnetic energy that an object radiates in the microwave region of the spectrum. A radar scatterometer measures the roughness of the sea surface, from which the direction and magnitude of the wind can be determined. A radar altimeter precisely measures the distance from a satellite to the surface of the earth, and can be used to map the true shape of the globe (or geoid).

* To obtain high resolution imagery from space with conventional radar would require an extremely large antenna due to the distances involved. A SAR uses the motion of the spacecraft to form a "synthetically" long antenna by recording data over a period of time.



A visible light image taken by a satellite of sea ice in the Bering and Chukchi Seas. (Photo courtesy of NOAA)



An image of pack ice in the Beaufort Sea from the synthetic aperture radar aboard the SEASAT satellite. (Photo courtesy of the Jet Propulsion Laboratory)

provided a wealth of data to both military and civilian oceanographers. The extensive analyses of the SEASAT data sets conclusively demonstrated that vital oceanographic parameters could be measured by microwave sensors from space.

No data set excited the oceanographic community more than that of the SAR, which produced imagery at resolutions comparable to those of optical systems. Until pioneering SAR work at NRL between 1973 and 1975, there was much concern that SAR, although enjoying great success in imaging terrain features, would not work well when imaging the ocean surface. The SAR not only imaged expected oceanic parameters, such as waves (surface and internal), boundaries of major currents, Gulf Stream eddies, and along shore currents, but also imaged some that were not expected. One of the most interesting of these was the imaging of patterns on the ocean surface that correlated with sea-floor topography. With this capability, the Navy now possesses a new hydrographic surveying tool useful in locating and positioning uncharted or mischarted hazards to navigation and for updating nautical charts. During the 1970s, NASA and the Defense Mapping Agency also demonstrated that another on-going satellite series, LANDSAT (which was designed to study agricultural and geological features over land) could be useful in the study of shallow water bathymetry. Data from this high-resolution optical system are presently being used to locate and chart worldwide hazards to navigation.

In the late 1970s, as rapid advances in spacecraft oceanography were being made (especially with the then planned launch of SEASAT), the Navy formulated the Navy Environmental Remote Sensing Program (NERSP). It had become evident that conventional measurements from ship and airborne instruments were insufficient to provide timely and accurate global oceanic environmental data and forecasts in support of our naval forces. As part of NERSP the Navy was directed by the CNO to prepare a statement of operational requirements needed for each of the Navy's primary mission areas. These requirements were reviewed and certified by the CNO, and early in 1977, a Navy Satellite Measurement of Oceanographic Parameters Operational Requirement (SMOP-OR) was formally established (Table 2).

Based on the requirements of the SMOP-OR, and following the success of SEASAT, the Navy in concert with NASA and NOAA proposed a follow-on oceanographic satellite to SEASAT. This satellite was designed to carry sensors that would, in conjunction with dedicated ground control and data processing systems, insure the delivery of remotely sensed data to meet the operational requirements of the fleet. This proposed follow-on was called the National Oceanic Satellite System (NOSS). A radar altimeter,

**Table 2. Satellite measurements of oceanographic parameters—operational requirements (SMPO-OR).**

| Parameters | Horizontal Resolution* | Accuracy* |
|---|---|---|
| **Surface-wind** | | |
| **Speed** | **10/25 km** | **2 m per sec/4 m per sec** |
| **Direction** | **10/50 km** | **±10°/22.5°** |
| **Sea-surface temperature** | **10/15 km** | **0.5/1.0°C** |
| **Sea vertical temperature structure** | **10/100 km** | **1.0/2.0°C** |
| **Waves** | | |
| **Significant height** | **10/25 km** | **0.3 m/10%** |
| **Amplitude components** | **1/25 km** | **0.3 m/0.7 m** |
| **Wavelength components** | **1/25 km** | **5%/15%** |
| **Direction** | **1/50 km** | **10°/45°** |
| **Ice** | | |
| **Cover** | **0.5/25 km** | **12%/30%** |
| **Thickness** | **2/50 km** | **0.5/2 m** |
| **Age** | **10/50 km** | **6/12 mos.** |
| **Icebergs** | **0.015/0.1 km** | **Position 0.5/2 km** |

*** Operational target/minimum acceptable threshold**

microwave radiometer, radar scatterometer and a visible and infrared color scanner would measure global winds, waves, sea-surface temperatures, sea ice, and oceanic chlorophyll concentrations. Unfortunately, the price tag for NOSS was too large, and it was cancelled.

However, since the need to satisfy the operational requirements still existed, the Navy went back to the drawing board, cut costs, and proposed the Navy Remote Ocean Sensing System (N-ROSS) satellite. This satellite was to carry four microwave sensors (a radar altimeter, a radar scatterometer, a microwave imager, and a microwave radiometer) to measure wind speed and direction, wave heights, geoid, sea ice, precipitation, and sea-surface temperatures. The N-ROSS program was approved and is now scheduled to be launched in 1990. As presently planned, the N-ROSS will fulfill the requirements laid out in the SMOP-OR. N-ROSS-II is already on the drawing board, with the addition of a SAR to its sensor payload being considered.

**Naval Remote Sensing Community**

The data collected through the various environmental satellites is useless unless it reaches those who need it. To this end, the Navy remote sensing community is organized under the Assistant Secretary of the Navy for Research, Engineering, and Systems into three distinct commands: 1) the Chief of Naval Research (CNR), who oversees basic research in remote sensing and ocean science (see page 12); 2) the Chief of Naval Development, who tests applicable basic research results through field experiments or in the laboratory; and 3) the Chief of Naval Operations (CNO), who supervises the transition from experimental results to operational systems. Since the Navy is the largest tactical user of space-based systems, the Naval Space Command was established in 1983 under the CNO. The Command's principal mission is to provide direct space systems support to the Navy worldwide. A Naval Space Technology Center was established this spring at the Naval Research Laboratory to preserve and enhance the Navy's strong space technology base and provide expert assistance in developing and acquiring space systems that support the Navy's missions.

**Space-Science**

With complex navigation and communication satellites orbiting the Earth and manned spacecraft a common occurrence, the Navy recognized the need not only to look down at the Earth but to look up and out into space to measure its environment as well. Our sun is frequently beset with storms that hurl large volumes of gas and electric energy fields into space. When directed toward Earth, these phenomena can cause communications blackouts and are a potential source of danger to man as he works outside the protective envelope of the Earth's atmosphere.

The Navy's Solar Radiation (SOLRAD) satellite is an example of a space-science program developed to keep the Department of Defense's (DoD's) worldwide communication links open. SOLRAD was conceived late in the 1950s at NRL and was designed to continuously monitor all aspects of the sun's activity. Special attention was given to the effects of radiation on the ionosphere, which had critical importance to communications. Armed with SOLRAD information, DoD communicators were able to select those radio frequencies that allowed them to best avoid solar interference. SOLRAD was the nation's longest continuing series of satellite projects dedicated to a specific research program, with satellites launched between 1960 and 1976. Presently, solar data are being supplied to DoD users through the NOAA geostationery meteorological satellite series.

Through its continuing work in space research, the Navy has played a major role in the field of space-science research since the 1940s. The Navy's role in solar and stellar physics enables it to provide much expertise for the space-science programs being carried out by other government agencies, such as NASA.

**The Future**

With extensive expansion planned for the U.S. fleet and with today's naval warfare scenarios becoming more and more complex, the Navy will need to maintain a role in space for many years to come.

It has been 25 years since the first visual observations of the oceans were made from a satellite in Earth orbit, and during the intervening years the Navy has depended primarily on operational and experimental meteorological satellites (which were designed to observe clouds, not through clouds) for oceanic environmental data. The design and development of multi-sensor, all-weather satellites, such as N-ROSS, will ensure the collection of the vitally needed oceanographic data that will not be available from any other planned U.S. remote sensing program.

Although no one sensor or satellite system will provide all the data needed by both operational commanders and research scientists, the data from N-ROSS, combined with data from the DMSP and civilian meteorological satellites, will make up a global environmental data set to support our naval forces wherever and whenever the need arises.

*Peter A. Mitchell is a physical scientist with the Space Sensing Branch, Naval Research Laboratory, Washington, D.C.*

*The carrier* U.S.S. Midway *and her battle group underway in the Indian Ocean. The* U.S.N.S. Passumpsic *is on the* Midway's *starboard quarter; a replenishment oiler is on the port quarter. She is flanked on port and starboard by the destroyer* U.S.S. Elliott *and the guided missile cruiser* U.S.S. England. *Protecting her bows are the destroyer* U.S.S. Robinson *to port and the fast frigate* U.S.S. Downes *to starboard. Carrier-launched fixed-wing aircraft and helicopters protect airspace to several hundred miles and provide an extended antisubmarine screen. Nuclear attack submarines patrol beneath the battle group to protect it from both submarine and surface ship attack. (U.S. Navy photo)*

# Antisubmarine Warfare

## by Robert C. Spindel

The security of our nation and the balance of world power depend on the submarine. Long an important part of naval warfare, the submarine's modern role is unprecedented. Fast, deep-diving, nuclear attack submarines (SSNs) form the major offensive unit of the Soviet Navy, and in the U.S. Navy serve to defend the carrier battle group, the basic unit of U.S. seapower.

The nuclear ballistic missile carrying submarine (SSBN) is a mobile, covert, almost invulnerable launch pad for long-range missiles. Because the submarine is so crucial to national security, many of its activities are necessarily kept secret, making it difficult to assess its ultimate importance. However, the United States and the Soviet Union are devoting impressive financial and technical resources to submarine technology and to the expansion of their submarine forces.

Both nations consider the submarine to be an essential element in their military arsenals; it is a major sticking point in arms-limitation negotiations. At the present time, the Soviet Union has approximately 375 submarines in service, about half of which are nuclear powered. The United States has a force of about 120, all nuclear powered. Both nations continue to build new, larger, more lethal submarines and submarine launched weapons.

Not so widely appreciated are the equally vigorous and expensive antisubmarine warfare (ASW) programs aimed at neutralizing the opponent's submarines. Nations with substantial naval forces, and those whose livelihoods depend on free access to the oceans, have large ASW research, development, and procurement programs, as well as vigilant ASW defenses. By far the greatest efforts are those of the United States and the Soviet Union, although there are significant activities in other countries, including England, Canada, France, Norway, Sweden, Australia, New Zealand, Japan, Italy, and West Germany. The North Atlantic Treaty Organization (NATO) staffs a laboratory in La Spezia, Italy, that has an ASW mission. The level of ASW


*The nuclear attack submarine* San Francisco *under way on the surface during sea trials. Submarines such as this are designed to protect surface shipping, battle groups, and ballistic missile submarines. They also are used to hunt and attack enemy subsurface forces. The attack submarine is equipped with active and passive sonars, high-speed torpedoes, and submarine-launched rockets. (U.S. Navy photo)*

activity in other free-world nations, such as Spain, the Netherlands, and Israel, is small, but not insignificant.

In the United States, ASW expenditures amount to more than $12 billion annually, about 15 percent of the Navy's total budget. There is no reason to assume that the Soviet Union devotes fewer resources to this military category.

**A Variety of Technologies**

Antisubmarine warfare involves a spectrum of military platforms—from aircraft to satellites, from surface ships to submarines. ASW sensors are drawn from a variety of technologies, including passive listening hydrophones based on the electrical properties of certain crystals, optical fibers whose refractive index varies with external acoustic pressure, infrared radiation, magnetic anamoly and low-light-level photon detectors, and magnetic and hydraulic devices that emit high-level sonic "pings" or low-level, surreptitious, hard to detect signals. For the final prosecution of an ASW action, the destruction of enemy submarines, there is a large arsenal of modern weaponry, including antisubmarine rockets, mines, depth charges, and nuclear-armed and conventionally-armed torpedoes.

To understand the importance of ASW to modern warfare and to national security one must appreciate the capabilities of the modern submarine and the differences between its tactical and strategic missions.

**The Modern Nuclear Submarine**

The submarine rose to prominence during World War I and II primarily as a tactical weapon. Submarine packs were employed to destroy enemy merchant and naval vessels. During World War II, German U-boats were enormously successful. They accounted for the loss of more than 2,800 merchant vessels belonging to the Allied powers, which almost led to a decisive victory over the Atlantic maritime nations.

Had the Germans concentrated on building their submarine force, they probably could have starved Britain into surrender, thereby denying the United States a European base of operations. Hastily organized ASW programs eventually succeeded in giving the Allies the upper hand. Sonar, torpedoes, depth charges, and other weapons were developed. Tactical procedures were devised to optimize the probability of finding, hunting, and destroying German submarines. Sonar was effective, even though its range was generally limited to several thousand meters. Listening devices launched from aircraft (sonobuoys) were invented to locate submarines. Torpedoes with higher speeds and more accurate firing systems were developed. The sonic properties of the ocean were poorly understood at the beginning, but toward the end of World War II ASW tactics took advantage of new information about how sound travels in surface waters and in a deep-sound channel near the bottom of the thermocline (seen *Oceanus*, Vol. 20, No. 2, 1977).

The submarine emerged from World War II as a major naval offensive and defensive weapon, but it did not achieve its present position of importance until the advent of nuclear power. This one giant technological achievement altered the mission of the submarine and catapulted it into the center of international politics. For the first time, it became a true submarine. Before, it had been a simple, albeit effective, tactical weapon.

The submarine previously had been primarily a surface vessel. It was driven by diesel engines that simultaneously charged the batteries used for propulsion during brief periods (measured in hours) of submergence. It spent most of its time on the


A P-3C Orion ASW patrol aircraft in flight. Sonobuoy launch tubes are visible in the center of the fuselage. The "stinger" that extends beyond the tail contains the magnetic anomaly detector, which signals the presence of a submarine by detecting its effect on the earth's background magnetic field. (U.S. Navy photo)*

surface because its diesels required large volumes of air. It had limited depth capability (hundreds of feet) and limited endurance. Except when running submerged, slowly, under electric power, it was noisy.

Antisubmarine warfare in those years depended on finding the submarine on the surface or detecting it acoustically. Submarines were hunted by aircraft using short wavelength radars, although their effectiveness was largely offset by the development of the snorkel. This device enabled a submarine to ingest sufficient quantities of air to run almost completely submerged most of the time and its small width made it practically undetectable by overhead radar.

The nuclear submarine is entirely different. Nuclear power frees it from dependence on surface supplied air. It can remain submerged for many months. Indeed, the duration of its underwater mission is probably limited only by its capacity to store food and oxygen for its crew and by their psychologic ability to endure close, crowded, and confined living conditions.

**Tactical and Strategic Missions**

The nuclear submarine is designed for speed and efficiency submerged, whereas its diesel-electric predecessor had to be designed for surface running. It is estimated that the modern submarine can outrun a World War II torpedo. It is armed with missiles that can be fired at shore targets thousands of kilometers distant so it can patrol in remote ocean regions far from defended coastlines. It can remain hidden by the cold and dark waters that cloak its movements. It can roam under cover of the arctic icepack. It is stealthy and covert, difficult to detect, to localize, and to destroy.

Because of this, the mission of the submarine has expanded. It no longer serves only in the tactical role of the World War II attack submarine. It now has a strategic mission as well, a mission with the crucial objective of maintaining world peace through nuclear deterrence.

For many years, the nuclear military policies of the Soviet Union and the United States have been based on the concept of assured destruction by retaliatory response to a preemptive first strike. Although there have been changes in our military strategy (see page 38), the precarious balance of world peace, even world survival, rests to large extent on this concept of mutual guaranteed loss. Simply put, no matter how cleverly, swiftly, or powerfully one side attacks the other, there will be an inexorable response, for which there is no defense, that will inflict massive, unacceptable

*A sonobuoy is loaded into a launch tube of a P-3C ASW patrol aircraft. The sonobuoy is a major ASW weapon. It has also been of great benefit to the civilian oceanographic research community where it has been used for decades for sea-floor seismic studies and for research into sound propagation in the ocean. (U.S. Navy photo)*

damage in return. This is the basis for the principle of nuclear deterrence in which opposing forces are held at standoff because of the certainty of retaliatory destruction. The game is never played because no one can win.

The submarine sea-based deterrent is one of the least vulnerable elements in the triad of strategic military forces, which consists of long-range bombers, land-based missiles, and submarine-launched ballistic missiles (SLBMs). It may be the deterrent with the highest probability of surviving a preemptive first strike because of the extreme difficulty of keeping track of all patrolling enemy SSBN's and destroying them before they can launch their missiles. The balance of world power is so dependent on the SSBN strategic mission that very substantial resources are devoted to sophisticated ASW programs that have as their goal the neutralization of nuclear powered ballistic submarines.

**Antisubmarine Warfare**

The ASW mission is executed in four phases; detection, identification, localization, and destruction. First the presence of the submarine must be detected. Then it must be identified as friend or foe, and its position determined so that forces can be dispatched to destroy it. Tactical ASW is designed to seek out and destroy enemy submarines that pose a threat to friendly shipping, or to protect shipping by intimidation. Strategic ASW is designed to destroy a major fraction of the enemy's ballistic missile carrying submarines before the missiles can be launched. The requirements for each mission have much in common and therefore are similar. In fact, there is an ambiguity in the tactical and strategic roles of ASW that creates difficulties in arms control negotiations. Once an ASW system is operational, it is difficult to say whether it is for the protection of shipping and commerce, or for locating and destroying missile carrying submarines.

Command, control, communications, and intelligence are vital ingredients in antisubmarine warfare. An ASW mission often requires the coordination of disparate and dispersed assets for confirmation of detection, unequivocal identification, precise localization, and certain destruction. A typical scenario might begin with acoustic detection by listening hydrophones, and then entail communication with a surface ship whose towed sonar array can confirm identification and reduce location uncertainty. An aircraft might be sent to the position established by the towed array to drop sonobuoys for pinpoint accuracy. Finally, sea-based or aircraft torpedoes and missiles might be launched. If the mission is one of strategic defense, then an attack submarine might be directed to keep an eye on the enemy SSBN. Computers would be used to predict the SSBN's future course and position so that it could be kept targeted without constant shadowing.

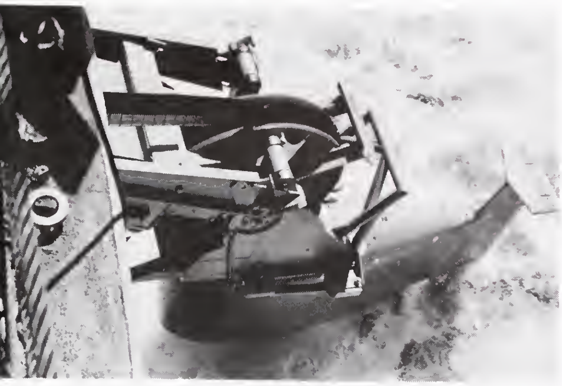
*This bow view of the destroyer* U.S.S. Spruance *(DD-963) shows the huge dome which houses ASW sonars. This ship is specially designed for ASW. (U.S. Navy photo)*

**Acoustic ASW**

Underwater acoustic techniques are by far the most effective and widely used ASW methods. The ocean is virtually opaque to light, and electromagnetic energy is so rapidly attenuated that it cannot penetrate usefully beyond several meters. On the other hand, sound can propagate thousands of kilometers with little loss. Underwater explosives detonated near New Zealand can be heard halfway around the world at Bermuda, and sonar pings can travel tens of kilometers, reflect off a target, and be heard quite clearly above the ocean background noise. Indeed, sound travels so well in the ocean that a large fraction of the ambient noise results from the sounds of distant shipping and other man-made sources, such as seismic exploration airguns and oil drilling rigs.

Passive sonar relies on the noise of submarines. Sounds are generated by the flow of water over the hull, machinery within the submarine, and by propeller rotation. These sounds radiate into the water and are sensed by underwater listening devices called hydrophones. The tones produced by propellers or rotating machinery are like fingerprints. They are used to classify the vessel type; sometimes they can identify a submarine right down to its serial number.

The United States and the Soviet Union employ passive sonar in extensive networks of undersea hydrophones located in virtually all the world's oceans, strategic straits, choke points, and essential seas. The U.S. system, known as the Sound Surveillance System (SOSUS), is designed to detect, identify, and localize submarines and surface vessels on an ocean-wide basis. It is a very capable ASW weapon, but advances in streamlined hull design and in machinery quieting, coupled with a rising level of ocean noise because of the proliferation of oil exploration and exploitation activities, reduce its effectiveness for long-range surveillance. Therefore, it is augmented with portable systems.



*Some sonars are towed aft to remove them from the vicinity of noise generated by the ship and to allow them to be operated at different depths. This enables the operator to use his sonar to best advantage under varying acoustic conditions, such as when surface ducts form. These channels confine sonar signals to just beneath the surface and make hull-mounted sonars ineffective for finding submarines. This variable-depth sonar can be lowered beneath the duct for effective surveillance. (U.S. Navy photo)*

*A MK-48 torpedo is lowered into the torpedo room of the* U.S.S. Stonewall Jackson *(SSBN-634), a nuclear-powered, ballistic missile carring submarine. The ADCAP (ADvanced CAPability) version of this torpedo is one of the most deadly ASW weapons in the U.S. Navy arsenal. (U.S. Navy photo)*

For example, localized passive listening is provided by sonobuoys. These air-launched, floating radios have hydrophones suspended at submarine depths. During their lifetime of about 8 hours they transmit acoustic data to Navy aircraft or helicopters. Both are equipped with signal-processing computers, and secure communication links to shore, or to carrier ASW operation centers, where targets are identified and localized automatically by computers.

A single suspended hydrophone provides omnidirectional detection; an array of sonobuoys gives directional reception so that targets can be localized. Sonobuoys deployed in picket-fence-like lines are very effective. Under development is a longer-lived passive device, the air-dropped Rapidly Deployable Surveillance System (RDSS), designed to augment SOSUS in strategic areas. Hydrophones also are lowered into the water from hovering helicopters that can move rapidly from place to place to confirm detections and pinpoint location.

The Surveillance Towed Array Sensor System (SURTASS) is a mobile, long-range, passive surveillance system. It consists of long hydrophone arrays towed behind Navy surface vessels. This system adds to SOSUS capability by allowing better identification and localization. It improves coverage in selected high-interest areas and fills in SOSUS gaps. Attack submarines are equipped with sensitive

hydrophone arrays that make them particularly effective threats to the SSBN.

Passive sonar is inherently covert and is therefore the acoustic ASW weapon of choice. But its detections are not always definitive. Active sonars, which depend on the reflective properties of the submarine hull, are used too. An acoustic ping is generated and the time taken for it to travel to the target, reflect from it, and travel back is a measure of target range. Target bearing is determined by transmitting or receiving in selected directions. The ping can be transmitted directly at the target, or it can be bounced off the ocean surface or bottom to increase detection range and provide a measure of covertness. The ping appears to come from a position not occupied by the sonar. Surface vessels usually have bow-mounted active sonars, although some have sonars towed aft to remove them from the ship's noise. The new Spruance- and Kidd-class destroyers have been carefully designed for ASW. Their machinery and hull noise has been minimized to increase their sonar effectiveness. Submarines have active sonars. The SH-60B helicopters has a dipping active sonar and there are even sonobuoys that can be commanded to actively ping. To combat active sonar, submarines are coated with special anti-noise materials to reduce their reflectivity and make them less detectable acoustically.

The decision to use active sonar during a tactical or strategic engagement is not taken lightly. Sonar pings immediately reveal one's presence.

### Non-Acoustic ASW

Acoustic systems are not the only ones used in antisubmarine warfare. Radar can still be effective during the rare moments when a nuclear submarine surfaces, or when it is running with its periscope exposed. Electronic counter measures (ECM) are used to detect emissions from submarines if they attempt radio communications. The nuclear submarine can remain submerged for months at a time, but, during its mission, it must communicate, however infrequently, with command and control authority. Elaborate, cryptographic coding systems are used to frustrate enemy surveillance; transmissions that appear to hop randomly in frequency foil detection by radio direction finders.

ASW aircraft have Magnetic Anamoly Detectors (MADs) that detect changes in Earth's background magnetic field caused by large, metallic submarines. The MADs are extremely effective for localization, but its detection ranges are limited since the aircraft has to fly almost directly over the submarine to spot it. Moreover, the new Alfa-Class Soviet submarine has a titanium rather than a steel hull, which produces a smaller magnetic anomaly.

There are other possibilities for non-acoustic antisubmarine warfare. The blue-green laser can penetrate many tens of meters beneath the surface. It offers the hope of airborne submarine detection. Low-light-level television, image intensifiers, photon detectors, and other visual technologies may be useful. Infrared techniques may be used to detect the heat given off by a submarine. As a submarine passes through the water, it produces a subsurface wake that may be detectable by aircraft or satellite sensors. Indeed, earth-orbiting satellites are expected to play an important role in future ASW systems by serving as a platform for sensors as well as a data and communication link between dispersed ASW forces and control centers. Both the United States and the Soviet Union have experimental satellites, and the U.S. Navy plans to launch N-ROSS, the Navy Remote Oceanographic Sensing System, later in the decade.

### ASW Weapons

Sensors detect, identify, and localize, but the final ASW action is the job of torpedoes, missiles, and mines. These weapons are launched from shore, surface ships, aircraft and submarines. The anti-submarine rocket (ASROC) is installed on frigates, destroyers, and cruisers. It delivers a small nuclear warhead to 15 kilometer ranges. The submarine rocket (SUBROC) has a larger payload and ranges up to 100 kilometers. It is launched from a torpedo tube, breaks the surface, flies through the air, and dives back into the sea to attack submarines.

There are two major torpedoes in the U.S. arsenal, the MK-48, which is a heavyweight weapon, and the MK-46, which is lightweight, and can be air-launched. They both have sophisticated sonar guidance systems and the speed, depth, and payload to detect and attack the latest Soviet submarines. The MK-48 has a control wire that allows its speed, course, depth, and other attack functions to be continuously refined as it approaches the target. Homing sonar provides the final guidance for impact.

Anti-submarine mines are very effective weapons because they are covert and can be laid near enemy home ports or essential passages. One of the latest, most advanced types is the CAPTOR (encapsulated torpedo) mine. It lies in wait continually evaluating data from its sensors until it identifies an enemy submarine, whereupon it launches a torpedo.

### Environmental ASW

The ocean has a highly variable sound speed structure that greatly affects the range and sensitivity of sonar. Ducts, formed by surface heating, confine sound to channels just beneath the surface. They can extend downward tens to hundreds of meters. The ocean has a deep sound channel that focusses submarine sounds so they can travel hundreds, even thousands, of kilometers. Frontal systems, such as the Gulf Stream and the eddies and rings that are found oceanwide, hamper sonar signals because they are characterized by severe temperature and sound speed changes. Submarines can hide beneath surface ducts to avoid detection by a surface ship, or above them to evade another sub. Eddies and fronts can mask a submarine or offer opportunities for tactical maneuvers. Because these environmental factors are so important, submarines and surface ships have instruments for on-site evaluation of sonar conditions. The also are supplied with sonar forecasts based on the environmental predictions made by the Fleet Numerical Oceanography Center (FNOC) in Monterey, California. In the future, it is expected that satellites, such as N-ROSS, will

*An SH-60B Seahawk helicopter landing aboard the guided missile frigate U.S.S. McInery in the Atlantic Ocean. This is the Navy's latest ASW helicopter. It is equipped with an integrated ASW capability known as LAMPS III, the Light Airborne Multi-Purpose System. (U.S. Navy photo)*

provide global oceanographic data useful in this context.

### Wither ASW?

Despite the tremendous variety of ASW activity, most experts agree that there is little likelihood that the nuclear submarine will be compromised by ASW developments either now or in the foreseeable future. Thus, the submarine will continue to be a cornerstone of U.S. and Soviet naval policy. It also will remain a principal element in international military and political strategies. While we cannot rule out undiscovered technologies, nor can we predict with assurance the limits of future applications of current technologies, it is unlikely that the situation will be drastically altered. However, even if major leaps in ASW capability are not likely, a steady improvement in the ability to detect, identify, localize, and destroy submarines will gradually yield a decided military advantage. This prospect will keep the international investment in ASW research, development, and procurement high.

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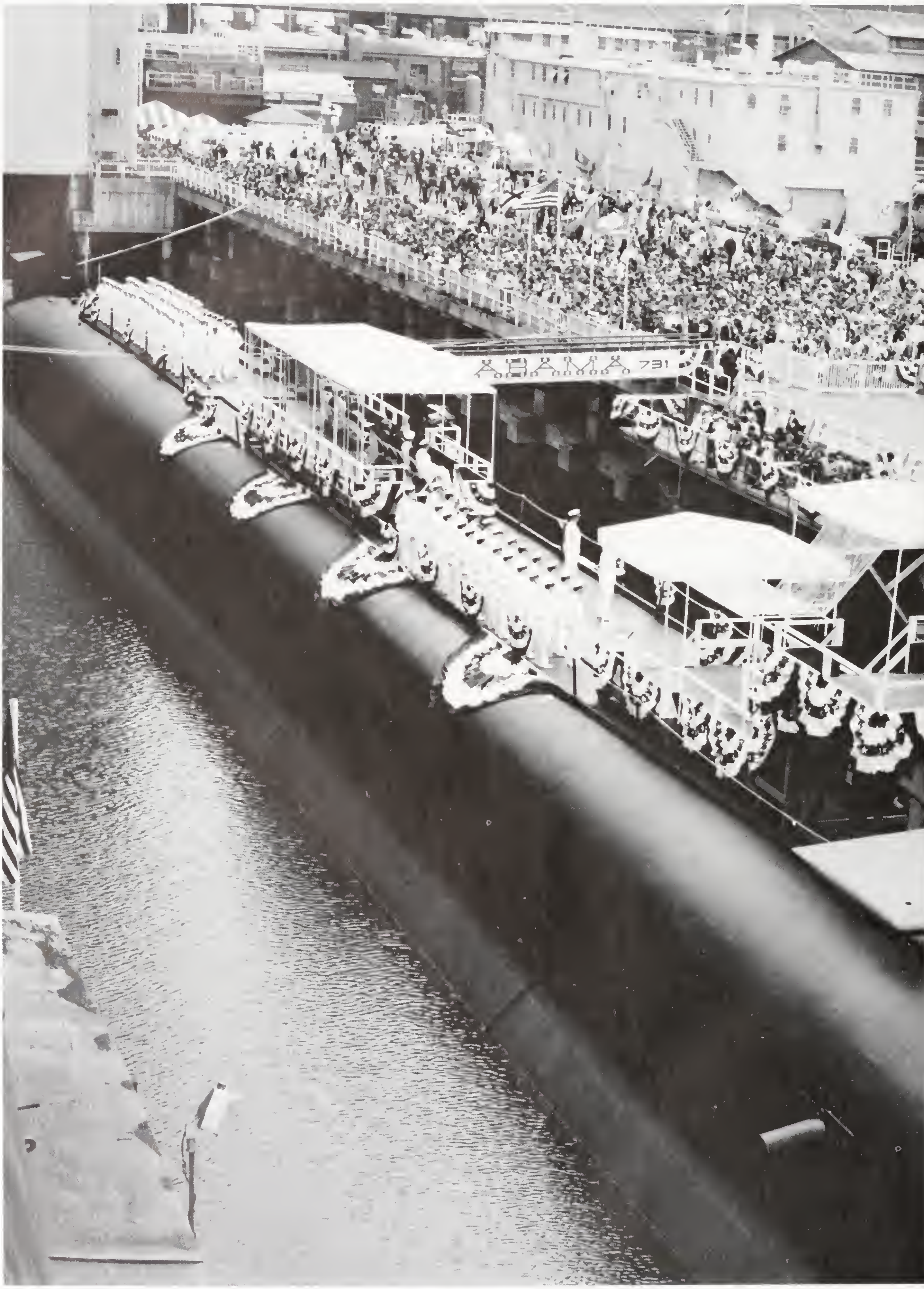
ABAMA 731


## View I—

# Trident's Role in National Security

## by J. J. Martin

A trident is a three-pronged spear, the symbol of a sea god in classical mythology. In modern times, it has become a symbol of naval supremacy. The Trident weapon system is aptly named.

The Trident program consists of the new, Ohio-class, nuclear-powered ballistic missile submarine (SSBN); the Trident I (or C-4) submarine-launched ballistic missile; and the Trident II (or D-5) missile (Table 1 and Figure 1). In 1982, the first Trident SSBN entered service, equipped with C-4 missiles; current plans call for deployment of one Trident submarine a year until at least 13 are in service. The C-4 missile is also deployed in 12 older Poseidon SSBNs (Figure 2). The D-5 missile is under development. The program has had strong Congressional support since its inception.

Trident is a major improvement over the earlier Polaris and Poseidon ballistic missile submarine programs in terms of its ability to survive a Soviet first strike, and still be able to launch a retaliatory strike. More importantly, Trident will have a more prominent role in U.S. military strategy than these earlier programs.

U.S. strategy trends, Soviet military capabilities, U.S. nuclear forces, and plans for their employment are such that the Trident is likely to be called on to carry out missions beyond second strike retaliation—the primary role for U.S. ballistic missile submarines in the past. Potential new missions include limited nuclear strikes; support of conventional operations; attacks on military targets that have been reinforced to withstand nuclear blast, heat, and radiation effects (hard-target counterforce); and participation in a strategic reserve force that can be withheld for an indefinite period in wartime. Trident is already beginning to assume some of these missions.

The D-5 missile will be able to effectively attack such hard targets as Soviet intercontinental ballistic missile (ICBM) silos. While this capability is

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*Launching ceremonies for the Trident submarine* Alabama. *(Photo courtesy of General Dynamics)*

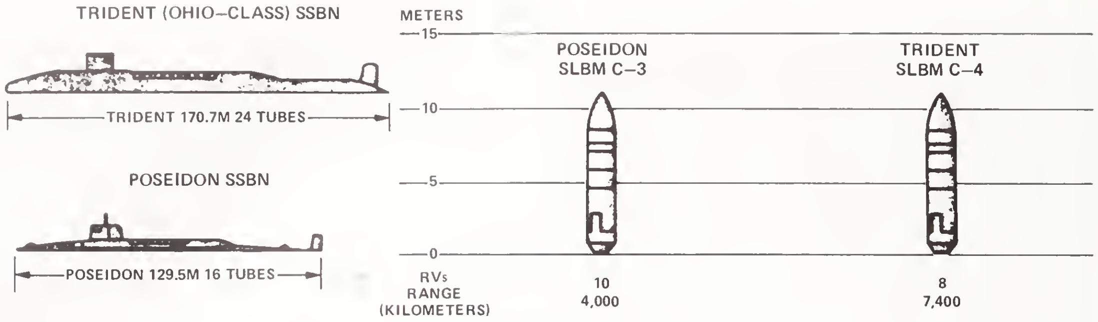



*Figure 1. The Trident and Poseidon submarines and missiles compared.*

controversial in some quarters, this author does not find it destabilizing. Because this counterforce capability will be extremely difficult to neutralize, it will reduce Soviet confidence in achieving any possible war aims, and consequently will enhance deterrence.

For all these reasons, the Trident weapon system reinforces deterrence and imposes the right kind of costs on the Soviet Union, costs that are likely to divert Soviet resources from more threatening offensive weapons.

## MAD: Context For Trident Design

Mutual assured destruction (MAD) was the basic concept underlying U.S. nuclear strategy in the 1960s and early 1970s. This concept held that deterrence was sufficiently served if U.S. strategic forces could survive a massive Soviet first strike and retaliate by destroying all major cities and most of the industrial capacity of the Soviet Union. The associated concept of the strategic triad also was formulated in the 1960s—high confidence was sought by having retaliatory abilities in each of three strategic force components (land-based ICBMs, submarine-launched ballistic missiles, and manned bombers), independently of the others.

Trident was conceived in the mid-1960s as an advanced follow-on to the Poseidon program, intended to hedge against Soviet anti-submarine warfare improvements. In its early development, the program was simply called the Undersea Long-range Missile System (ULMS).

Two issues dominated the debate about ULMS. One was the extent to which SSBN quieting and increased operating area (achieved through the use of a longer-range missile than the Poseidon C-3) were adequate to ensure SSBN survivability in the future. The other, related issue was the trade-off between a smaller force of large SSBNs and a larger force of small SSBNs.

The Navy and the Office of the Secretary of Defense decided that quieting and a longer-range missile would sufficiently hedge against Soviet anti-submarine warfare advances that a smaller force of large SSBNs, each with 24 missile tubes, could be procured. This force had lower costs than larger force options with the same number of reentry vehicles. ULMS became the Trident program in 1974, when construction of the first Ohio-class nuclear ballistic missile submarine started.

When the basic decisions were made about Trident characteristics, the principal role envisioned for the system was second-strike retaliation against urban-industrial targets (and soft military targets). The 1980s and beyond was seen as a period of significantly increased threats to land-based ICBMs and manned bombers, so it was vital to strengthen the submarine leg of the triad. By the mid-1970s, however, important changes were taking place in U.S. nuclear strategy which portended additional roles for Trident.

**Table 1. The Trident program.**

| | |
|---|---|
| Ohio-Class SSBN | |
| First Deployed | 1982 |
| Launch Tubes Per Submarine | 24 |
| Trident I (C-4) Missile | |
| First Deployed | 1979 |
| Maximum Range | 7,400 Kilometers |
| Number of Reentry Vehicles | 8 |
| Accuracy (Circular Error Probable) | 450 Meters |
| Warhead Yield | 100 Kilotons |
| Trident II (D-5) Missile | |
| Scheduled Deployment | 1989 |
| Payload | Larger Than C-4 |
| Accuracy | Greater Than C-4 |

## A New Strategy

During the early 1970s, the White House, Pentagon, and State Department formulated a major revision in U.S. nuclear strategy. In contrast to MAD, which reflected purely Western values and totally ignored the question of what to do if deterrence fails, the revised strategy focuses on what Soviet leaders believe about deterrence and on retaliatory threats to things valued highly by Soviet leaders. It seeks thereby both to improve the basis for deterrence and to deal with the disconcerting issue of how to bring a nuclear war to an end short of holocaust, should deterrence fail (Table 2).

The Soviet Union believes that there will be tremendous damage in a nuclear war, but that one side will be the victor. For the Soviets, deterrence consists not of threatening cities, but of having forces strong enough to defeat the adversary.

Soviet leaders place high value on assured control over domestic elements, East European satellites, and borders with potential enemies, such as China. They require high confidence of success before embarking on military operations.

Therefore, the new strategy calls for nuclear force capabilities, operational concepts, and targeting that would reduce Soviet leaders' confidence in achieving their political-military objectives in war, and would threaten their political control. Central to this strategy is a wider range of options for the employment of nuclear weapons than previously existed, including options limited in size, geographic area, and target types. Strategic force options designed to support theater commanders are also required.

A wider range of discriminate options against military targets, which would result in little or no direct damage to civilians, is intended to provide responses to Soviet attacks while controlling escalation by leaving the Soviets with a continued stake in prudent behavior. The strategy retains large-scale nuclear attack concepts and calls for a secure reserve force to hold urban-industrial targets at risk during wartime as an added threat to induce the Soviets to stop fighting and negotiate.

These changes were and still are controversial. They suggest that nuclear wars can be fought in a measured, rational way, and provide added impetus for the development of hard-target counterforce capabilities, which some view as destabilizing. But the new strategy has had the full support of the Nixon/Ford, Carter, and Reagan Administrations and key members of Congress. Despite charges by critics, its purpose is not to "win" a nuclear war. Rather, the intent of the strategy, in the words of Harold Brown, former Secretary of Defense, is to enhance deterrence by making ". . . a Soviet victory as improbable (seen through Soviet eyes) as we can make it, over the broadest plausible range of scenarios."

The Trident program clearly is consistent with many aspects of the new strategy. Because of the Ohio-class SSBN's likely ability to survive for a long period under a variety of wartime conditions, it is a natural candidate for the secure reserve force. The C-4 missile has ample capability against soft military and civilian targets; with its planned accuracy improvements, the D-5 missile will have a hard-target capability.

The Trident program is also consistent with the arms control agreements negotiated in the 1970s. Multiple Independently-targetable Reentry Vehicles (MIRVs) on the C-4 (and, in the future, D-5) missile hedge against rapid Soviet deployment of a widespread ballistic missile defense system in violation of the ABM Treaty. Planned Ohio-class SSBN force levels taken alone are consistent with SALT I and SALT II limits on strategic offensive forces. In 1985, however, the United States

*A Trident I missile launch. (U.S. Navy photo)*

Table 2. Contrasts between MAD and current U.S. nuclear strategy.

| MAD | Current Strategy |
|---|---|
| ■ Deterrence by Assured Second-Strike Capability Against Urban-Industrial Targets | ■ Deterrence by Denying Soviet Confidence in Achieving Wartime Objectives |
| ■ Massive Nuclear Attack Options | ■ Wide Range of Limited and Massive Nuclear Attack Options |
| ■ Indiscriminate Destruction | ■ Capability for Highly Discriminate Attacks, With Low Civilian Damage |
| ■ No Requirement for Counterforce Capabilities | ■ Capability to Attack Military and Civilian Targets |
| ■ No Explicitly Designated Secure Reserve Force | ■ Secure Reserve Force |
| ■ Focus Only on Strategic Forces | ■ Encompasses Strategic and Theater Nuclear Forces |
| ■ Disparity Among Force Acquisition, Force Employment, and Declaratory Policies | ■ Consistent Acquisition, Employment, and Declaratory Policies |

must decide whether to withdraw some Poseidon SSBNs from active service in order to remain within these limits, which are not now legally binding, as it continues to deploy Ohio-class SSBNs.

## Emerging Trident Issues

Events are forcing changes in the classic U.S. triad concept, where each strategic force component has an independent ability to attack most important targets. These changes are likely to cause Trident to play a more prominent role in future strategic plans, assuming missions which in some cases are controversial and in some cases are not altogether to the liking of the Navy.

Many of the events causing these changes are taking place in the Soviet Union. An unprecedented and sustained period of high military investment there has resulted in a significant increase in Soviet military capabilities relative to those of the United States. Soviet missiles now pose a major first-strike threat to U.S. ICBMs and the trend is worsening. Ballistic missile defense research and an extensive radar network now permit the Soviet Union to deploy a nationwide anti-ballistic missile system relatively quickly, should it choose to violate the limits of the ABM Treaty.

The Soviet Union historically has valued defenses more than the West. Recent Soviet air defense improvements are directed toward countering U.S. manned bomber and cruise missile programs, and may make it more difficult for these forces to carry out their missions in the future.

While the Soviets have not achieved major breakthroughs in their ability to locate and attack SSBNs at sea, they have vigorous research and development programs in both acoustic and nonacoustic antisubmarine warfare. About 200 Soviet attack submarines are currently the main threat to U.S. SSBNs. This attack force now consists of many older, less capable vessels, but the Soviet Union is in the midst of a major program to upgrade its attack submarines (Figure 3).

In sum, the Soviet Union now poses a major first-strike threat to U.S. ICBMs, has significantly increased the capabilities of its defenses against


Figure 2. U.S. and Soviet SSBN deployments.

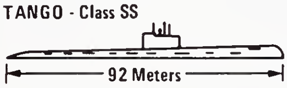
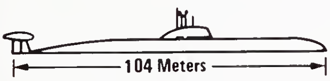
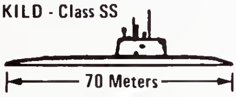
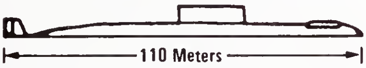
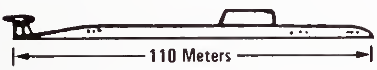
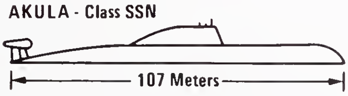
| | FIRST DEPLOYED | NUMBER DEPLOYED | ARMAMENT | PROPULSION | SUBMERGED DISPLACEMENT (Metric Tons) |
|---|---|---|---|---|---|
| TANGO - Class SS   | 1973 | 18 | TORPEDOES, POSSIBLE ASW MISSILE | DIESEL | 3,900 |
| VICTOR III - Class SSN   | 1979 | 17 | TORPEDOES, SS–N–16 ASW MISSILE | NUCLEAR | 6,300 |
| ALFA - Class SSN   | 1978 | 6 | TORPEDOES, SS–N–15 ASW MISSILE | NUCLEAR | 3,700 |
| KILO - Class SS   | 1980 | 4 | TORPEDOES | DIESEL | 3,000 |
| MIKE - Class SSN   | 1983 | 1 | TORPEDOES, ASW MISSILE | NUCLEAR | 9,700 |
| SIERRA - Class SSN   | 1984 | 1 | TORPEDOES, ASW MISSILE | NUCLEAR | 8,000 |
| YANKEE - Class SSN   | 1984 | 1 | TORPEDOES, LAND-ATTACK CRUISE MISSILE | NUCLEAR | 13,000 |
| AKULA - Class SSN   | 1985 | ON SEA TRIALS | TORPEDOES, ASW MISSILE | NUCLEAR | 8,000 |

*Figure 3. The most modern Soviet attack submarines, which are the primary threat to U.S. SSBNs.*

manned bombers, and continues to commit large resources in an effort to counter U.S. SSBNs.

Technology offers a means for the United States to maintain a balance of strategic forces with the Soviet Union. These new technologies, combined with trends in Soviet military forces and U.S. domestic politics, are moving the U.S. triad to rely more heavily on manned bombers, submarine-launched ballistic missiles, and cruise missiles, with reduced emphasis on land-based ICBMs.

The United States will begin fielding the B-1B bomber in 1986, continues with the Trident program, is deploying air-launched cruise missiles on B-52s, and is starting to fit ships and submarines with the nuclear-armed Tomahawk land-attack cruise missile (see page 55). There is, however, concerted and sustained opposition to new land-based ICBMs, at least as represented by the MX

missile. To a considerable extent, critics of MX have focused on the problems of finding a basing plan that is satisfactory from environmental, military, and cost perspectives. Just beneath the surface, however, is opposition to the high accuracy and large payload of MX, which gives it a significant hard-target counterforce capability.

Whether the MX ever will be deployed in militarily significant numbers is questionable. Whether the small ICBM program now being considered encounters similar political difficulties when it nears deployment remains to be seen. Recent administrations have emphasized the need to negotiate reductions in land-based ICBMs. President Reagan has made the MX into a bargaining chip, lobbying strongly for continued MX funding in order not to undercut the U.S. position in the recently renewed arms control talks. It is likely, therefore, that some combination of arms control and the politics associated with ICBMs will limit the part played by land-based missiles in future U.S. strategic plans.

Trident already has major roles in supporting large-scale nuclear attack options and in providing an element of the secure reserve force. Should the foregoing assessment be correct, Trident's part in the secure reserve force will become even more important. Moreover, the Trident D-5 missile over time could be required to assume the counterforce role against time-urgent hard targets that has been assigned to land-based missiles. Depending on the extent to which European politics permit continued modernization of NATO's intermediate range nuclear force, much of which still consists of tactical aircraft that are vulnerable to a nuclear first strike, Trident may also be required to support conventional military operations in Europe with a variety of limited nuclear options.

As land-based ICBMs contribute less to the second-strike capability of U.S. strategic forces, high SSBN survivability over the 20–30 year life of Trident will become even more vital. Moreover, if Trident must provide limited nuclear options against Soviet hardened installations or theater targets, plans may have to be developed for launch of only part of an SSBN's missiles. It would then be important to assure the continued survival of that SSBN, a problem complicated by the fact that the partial missile launch would provide indications of the submarine's location to Soviet sensors.

The extended range of the C-4 and D-5 missiles and the quieting advances in the Ohio-class SSBN are important for high survivability of the Trident weapon system. Depending, however, on Soviet anti-submarine warfare advances, Trident may in the 1990s or beyond have to rely more on countermeasures, tactics, and support by general purpose forces to survive in an extended war. While Trident survivability is likely to remain high because of the complexity and variability of the ocean's background noise, greater dependence on operational maneuvers and tactics will make Trident survivability less predictable. This potential change from today's virtually unquestioned SSBN survivability to a condition of less predictable (but not necessarily reduced) survivability will probably cause the Navy to resist assignment of new missions to Trident and may over time undercut the solid Congressional consensus on funding new ballistic missile submarines.

Since the nuclear-armed Tomahawk Land-Attack Missile (TLAM-N) is now being deployed aboard surface ships and submarines, it may be asked whether Trident and this cruise missile are unnecessarily redundant. While the effectiveness of both depends upon survival of sea-based launch platforms, each poses different problems for Soviet defenses. The Tomahawk imposes major costs on Soviet air defenses and Trident would present considerable difficulties to an expanded Soviet ballistic missile defense. Each system hedges against different kinds of advances in Soviet defenses; both may force the Soviets to divert resources from offensive weapons to defensive ones.

The D-5 missile will have sufficient accuracy to attack Soviet hard targets such as missile silos. Although recent Department of Defense reports to Congress have noted this development, it has not yet become the subject of controversy, perhaps because critics of ballistic missile accuracy improvements currently are concentrating on defeating the MX.

Opponents of high missile accuracy generally believe that a second-strike retaliatory capability against Soviet cities is sufficient to preserve deterrence. They view the hard-target counterforce capability of accurate MIRVed missiles as destabilizing, arguing that it threatens the other side's deterrent force, stimulating the arms race in peacetime and increasing Soviet incentives to launch their ICBMs early in a war, before they can be destroyed by U.S. attacks.

But there is ample evidence that the Soviet Union does not subscribe to the MAD theory of deterrence and the associated stability concepts. Highly accurate missiles based in a survivable mode (such as D-5) are essential for controlling escalation by keeping attacks precise and discriminate, should deterrence fail. Moreover, many defense planners believe improved U.S. threats to hard targets are needed to counter existing Soviet threats to U.S. ICBM silos. Restoring this balance will reduce the risk of war by reducing the confidence of Soviet leaders in achieving their war aims. Further, U.S. threats to Soviet ICBM silos are as likely to lead to negotiated reductions as to a heightened arms race. It was the threat posed by the U.S. Safeguard ballistic missile defense system that convinced the Soviet Union to negotiate the ABM treaty in the early 1970s.

Nevertheless, the hard-target kill capability of the Trident D-5 missile is likely to become more controversial as the missile nears deployment.

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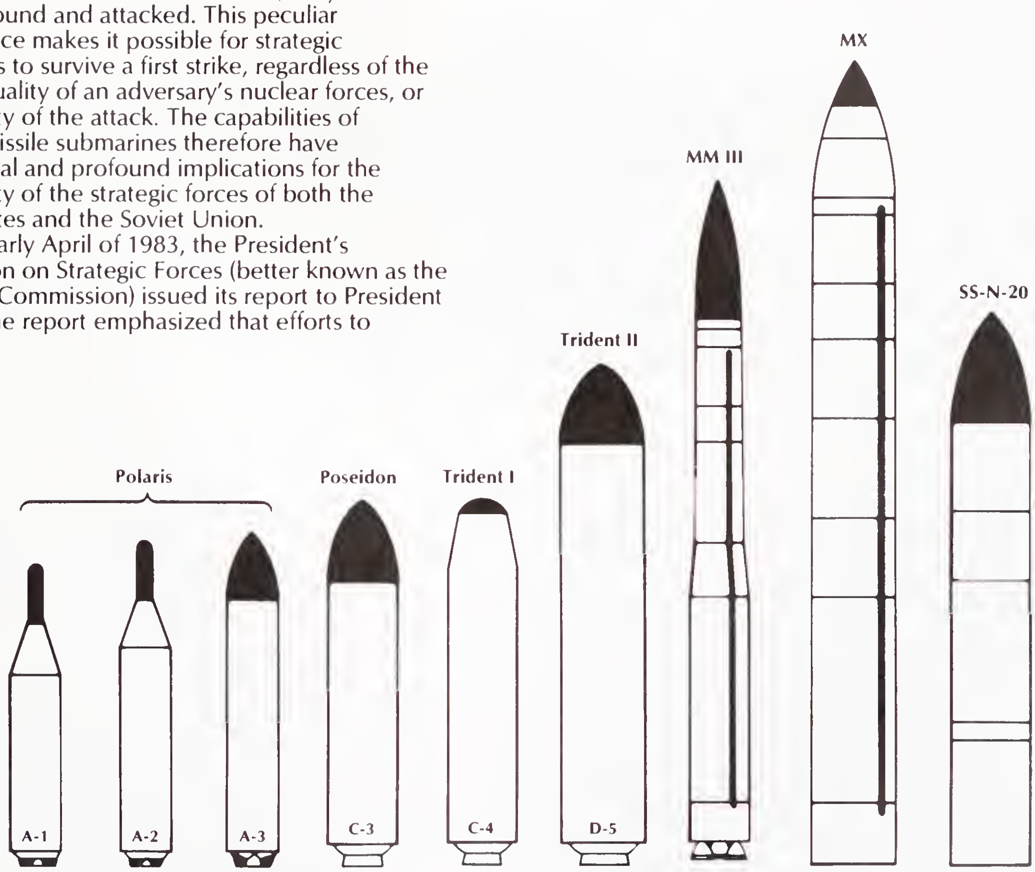
## View II—

# *The Trident and Strategic Stability*

**by Theodore A. Postol**

Because submarines carrying strategic missiles can be hidden in vast areas of the oceans, they cannot easily be found and attacked. This peculiar circumstance makes it possible for strategic submarines to survive a first strike, regardless of the size and quality of an adversary's nuclear forces, or the intensity of the attack. The capabilities of strategic missile submarines therefore have fundamental and profound implications for the vulnerability of the strategic forces of both the United States and the Soviet Union.

In early April of 1983, the President's Commission on Strategic Forces (better known as the Scowcroft Commission) issued its report to President Reagan. The report emphasized that efforts to




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **RANGE** | **1,200 NM** | **1,500 NM** | **2,500 NM** | **2,500 NM** | **4,000 NM** | **4,000 NM** | **~6,000 NM** | **~6,000 M** | **~4,500 NM** |
| **LENGTH** | **29.5 ft** | **31.0 ft.** | **31.2 ft** | **34.2 ft** | **34.2 ft** | **~44 ft** | **59 ft** | **71 ft** | **~49 ft** |
| **DIAMETER** | **54 in.** | **54 in.** | **54 in.** | **74 in.** | **74 in.** | **~83 in.** | **66/52 in.** | **92 in.** | **~90 in** |
| **WEIGHT** | **29,000 lbs** | **33,000 lbs.** | **35,000 lbs.** | **64,000 lbs.** | **~73,000 lbs** | **~120,000 lbs** | **~78,000 lbs** | **~193,000 lbs** | **~155,000 lbs** |

**NM = nautical miles**

*Figure 1. The six left-most missiles are all U.S. submarine launched missiles. The Minuteman III (MM III) is a silo-based missile that carries three warheads with an explosive force of about 300 kilotons, and the MX is a larger silo-based missile that will carry 10 warheads of roughly the same or slightly higher yield. The SS-N-20 is a new Soviet missile, deployed on the new Soviet Typhoon class submarine. Data on the SS-N-20 are speculative.*

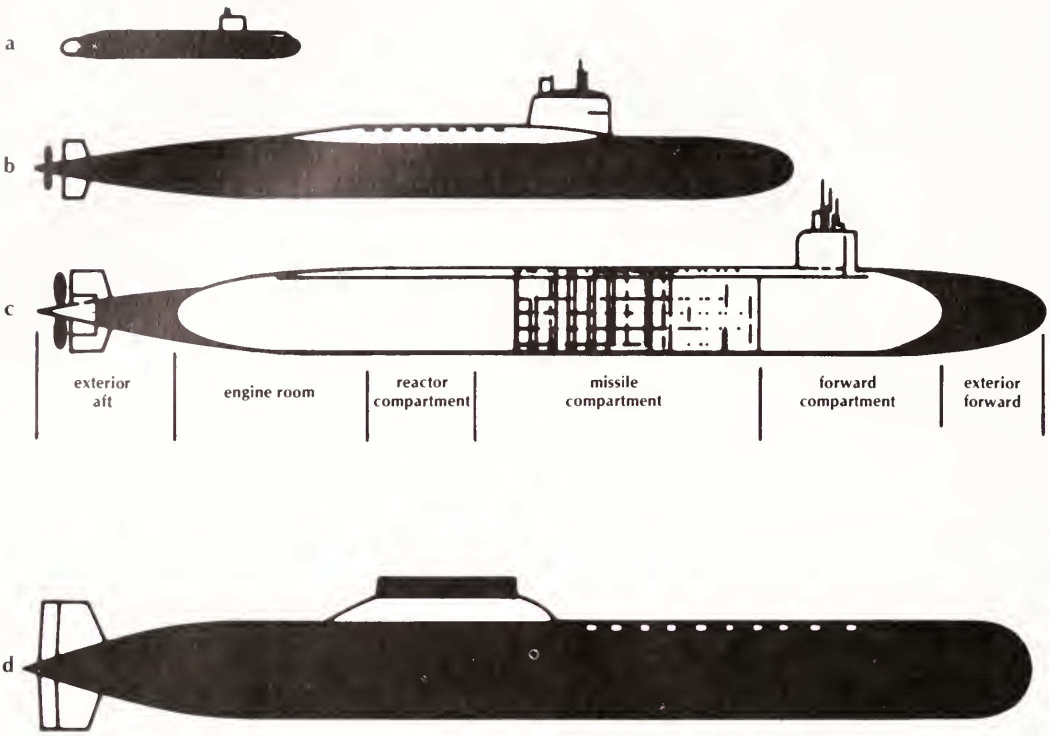



*Figure 2. Four nuclear powered submarines. a) The nuclear-powered ocean research submarine NR-1. This submarine is about 136 feet long and has a submerged displacement of 400 tons. b) The* Lafayette/*Poseidon class submarine has a length of 425 feet, a hull diameter of 33 feet, a submerged displacement of 8,250 tons, and can carry 16 Trident I missiles. c) The still larger* Ohio/*Trident class submarine is 560 feet long, has a hull diameter of 42 feet, displaces 18,700 tons when submerged, and can carry 24 Trident I missiles. d) The Soviet Typhoon class submarine has a considerably greater displacement, about 25,000 tons. It carries 20 nearly ICBM-sized SS-N-20 missiles (see Figure 1).*

modernize U.S. strategic forces should be channeled in directions that enhance long-term "strategic stability." In the context of the Commission's report to the President, strategic stability exists when neither the United States nor the Soviet Union has incentives to launch a preemptive nuclear attack (or first strike) on the other.

Two possible destabilizing circumstances were explicitly discussed in the report. In the first, one or both adversaries have an incentive to strike first, in hopes of destroying much of the opponent's forces and thereby improving their strategic position vis-à-vis the other. The second circumstance is when one or both adversaries have an incentive to strike first in order to avoid the loss of their forces from the other's attack. These two circumstances may exist simultaneously for either or both powers.

While the concept of stability may have some analytic utility, it is nevertheless an abstraction of highly uncertain meaning. Most significantly, it suggests that decisions might be made on the basis of perceived military advantages, rather than in consideration of the unimaginable levels of destruction that would surely accompany even a limited use of nuclear weapons. This view of stability, however, has been the basis of much of the U.S. strategic debate. For this reason, it may be instructive to apply it—even with a full appreciation of its limitations—to the question of whether or not the Trident sea-launched ballistic missile (SLBM) system is a destabilizing weapon.

**ICBMs and Stability**

Any discussion of strategic stability that builds on the definition used by the President's Commission cannot be limited to an examination of sea-based systems alone, but also must include those stability issues raised by the capabilities and vulnerabilities of other weapon systems.

The forces most clearly subject to preemptive attack are fixed, silo-based intercontinental-range ballistic missiles (ICBMs). Unlike submarines, which are almost invulnerable to attack while hidden in the ocean, or bombers, which can be put in the air without committing them to attack, on detection of an incoming attack ICBMs must be either written off or quickly launched. In addition, it is often argued (incorrectly, in the view of this author*) that silo-based forces have the greatest military capability because they combine powerful warheads with great accuracy, a combination that allows them to destroy

even the most heavily fortified (or hardened) targets. This ability is known as hard-target kill capability.** Thus ICBMs have the ability to attack well-protected command centers and other well-protected military installations. These missiles combine high capability with high vulnerability, making them very attractive targets for preemptive attacks that would, at least on paper, result in a strategic advantage to the attacker.

**The Trident Weapon System**

The Trident weapon system is America's newest submarine-based strategic missile system. The system currently is built around the Trident I or C-4 long-range missile (Figure 1). According to *Jane's Weapon's Systems*, the missile weighs about 70,000 pounds, and is designed to deliver eight 100-kiloton*** warheads with high accuracy from a range of up to about 4,000 nautical miles.

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* Since SLBMs cannot be found, and hence, cannot be attacked, they would be unaffected by a preemptive attack, or by delays in decision-making and communications. Thus, regardless of enemy action, SLBMs would be able to attack such militarily important targets as airfields, ports, staging areas, rail and highway junctures, war supporting and related industries, nuclear storage sites, possible troop concentrations, and command centers.

In contrast, the military value of ICBMs against these targets is less certain, since they can be preemptively attacked. A countervailing argument is that this drawback is offset by the fact that ICBMs have, or will have, an ability to destroy an enemy's silo-based ICBMs.

In fact, ICBM warheads take about 30 minutes to reach their targets, which makes it technically possible for one side to launch its ICBMs before the other's warheads arrive. No military planner (U.S. or Soviet) could therefore have confidence that enemy ICBMs could be attacked successfully. Equally, no commander could plan with confidence that his own ICBMs could be successfully launched if the enemy attempts to destroy them.

Thus, from the point of view of the prudent planner, ICBMs would have to be regarded as highly inflexible, having no capability unless they are used in a preemptive mode, or successfully launched prior to the arrival of warheads from an enemy preemptive attack. However, the SLBM, unlike the ICBM, does provide assured capability against all targets that can reasonably be expected to be subject to attack. By this measure of conservative military planning, its military value undeniably surpasses that of the ICBM.

** Capable and capability, as used in this article, refer to the ability of a strategic weapon to destroy fortified targets. Such capability is determined by the accuracy of the weapon, the power (or yield) of the nuclear warhead, and the reliability of the delivery system.

*** The destructive force of nuclear warheads is measured in kilotons and megatons, which indicate, respectively, a power equal to the destructive force of a thousand or a million tons of TNT. Extremely large conventional bombs have a yield of on the order of 0.005 kilotons. The bomb that destroyed Hiroshima had a yield of about 13 kilotons.

At the end of 1989 or beginning of 1990, the larger, more capable Trident II or D-5 missile will be deployed. If this larger missile utilizes propulsion technology similar to that used in the Trident I, scaling by volume indicates that it should weigh about 120,000 pounds, and should carry about 60 percent more weight. Scaling from weight and range data on other solid-propellant missiles (Minuteman III and MX) indicates that the Trident II should carry from seven to nine warheads, each with a yield of 300 to 600 kilotons. When the Trident II missiles begin deployment in 1989, the Soviet Union will be confronted with the most capable nuclear weapon system yet to be invented, an almost invulnerable sea-based missile that has accuracy and payload capabilities equal to those of the MX.

The Trident I missile is currently deployed aboard two different types of U.S. ballistic missile submarines: the 16-tube *Lafayette/Benjamin Franklin* (or Poseidon) class submarine, and the much larger and more modern 24 tube *Ohio* (or Trident) class submarine (Figure 2). Because the Trident II missile will be so much larger than the Trident I, it will only be deployable on the larger Trident submarine.

In addition to missiles aboard nuclear submarines, the Trident weapon system includes navigational, fire-control, and guidance systems. Of particular significance is an improved navigation system, which provides the missile's guidance system with highly accurate data about its launch location, velocity, and direction to target. In addition, the missile guidance system utilizes a star-tracker, which allows the missile to further correct for navigation and guidance errors before the dispensing of warheads. The result of these technological innovations is a sea-based missile of vastly improved accuracy.

**The Question of Stability**

There are three concerns that have been raised about Trident's effects on stability: that it could tempt the United States into a first strike; that it would force the Soviets to adopt a position of launching their missiles on warning of an attack, thereby increasing the likelihood of accidental war; and that it will reduce the decision-making time available to the Soviets in a crisis.

Since the bulk of Soviet strategic capability currently resides in silo-based forces, the development by the United States of a sea-based missile capable of attacking such forces has raised concern among some that Trident II would be destabilizing (Figure 3), since, according to this view, it would provide U.S. leadership with the tempting option of destroying most Soviet nuclear forces, the execution of which would result in U.S. strategic advantage.

An additional concern, which is perhaps more realistic, is that Soviet measures to prevent the destruction of their silo-based military forces in the face of Trident II would increase the likelihood of accidental or inadvertant nuclear war. Furthermore, since the silo-based forces would be regarded as vulnerable, plans that called for the withholding of such forces would not be militarily sensible. Thus, it

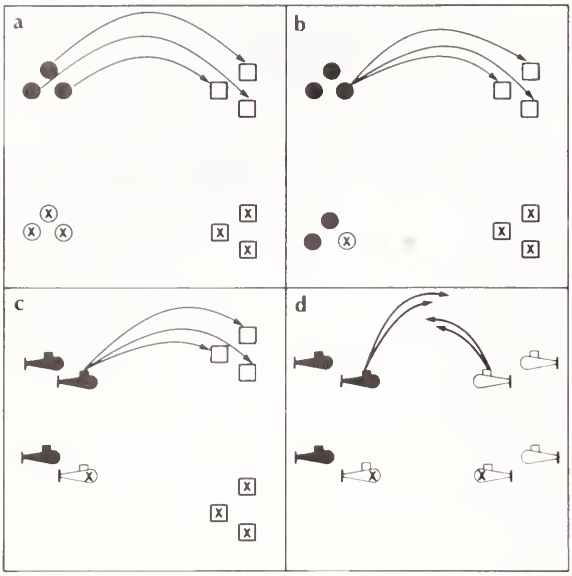



*Figure 3. Some configurations of nuclear forces relevant to the concept of strategic stability. a) If each side has a force of single-warhead silo-based missiles, the attacker disarms himself in the process of disarming his adversary. Since neither side can achieve a strategic advantage as an outcome of such an attack, this circumstance is considered to be "stable." b) One or both sides now have multiple warhead missiles based in silos. In this circumstance, a successful "first-strike" could result if only a fraction of the missiles in one force destroy the other force. Since the outcome of a successful attack results in the strategic "superiority" of the attacker, an incentive is created to "go first." This circumstance is considered "unstable" or "destabilizing." c) In this scenario one side has invulnerable sea based forces that have missiles of sufficient accuracy that a disarming first-strike against the other is technically possible. This circumstance is also unstable according to the criteria of the President's Commission. However, because neither side has a strong incentive to go first, and only one side is forced to adopt a hair-trigger posture, there are fewer opportunities for errors or misjudgments that could lead to an accidental exchange. This situation is therefore less unstable than the situation illustrated in (b). d) In still another possible circumstance, both sides have invulnerable sea-based forces armed with highly accurate missiles. Although both sides have considerable capability against hardened targets, neither side would have an option to disarm the other. This situation is therefore stable. It is important to bear in mind that any of the exchanges postulated above could well involve the detonation of hundreds or thousands of high-yield warheads, resulting in deadly fallout. In addition, if silos are in grassy or forested regions, fires could result over areas of tens or even hundreds of thousands of square miles, with potentially disastrous effects on the atmosphere and climate. Thus, while the above concept of stability may have some analytic utility, it does not capture the absolute consequences of even a "limited" attack. The planetary scale of nuclear effects from attacks and counter-attacks clearly would weigh heavily on the mind of any rational, informed decision-maker.*

is argued, the hard target kill capability of the Trident II simultaneously denies the Soviets the option of withholding part of their silo-based force and coerces them to adopt measures to assure a rapid launch. Therefore, the result of Trident II deployment would be an increase in both the likelihood of accidental nuclear war and the likelihood that such a war would result in a total exchange of both U.S. and Soviet forces.

These concerns about technological developments that could lead to accidental or inadvertant nuclear war, however remote or implausible they may seem, are understandably most disturbing. Furthermore, arguments that "they would go first, but we never would" simply do not address the security dilemmas faced by super-power leadership in the nuclear age.

Experience has shown that when national leadership is subject to the extreme pressures of a crisis, signals can be misread and misjudgments can occur. In addition, casual and careless statements of high-level government officials, or impressions created by military officials writing about fighting and winning nuclear wars, may lead to misimpressions that could result in dire actions during a crisis.

This is especially so when one considers that leadership might have to function through an extended period of crisis, constantly tortured by the knowledge that at any instant, they might receive warning that in less than 20 to 30 minutes their country would be hit by enemy warheads. After an extended period of such stress, it is entirely possible—in fact it might even be expected—that decision-makers would feel pressured to act on issues of momentous importance even though available time and information might be inadequate.

This concern has been exacerbated by the claims of some that the Trident II will greatly reduce the warning time available to the Soviet Union. While this concern should not be dismissed, the case is not as clear cut as one might expect.

The Soviet Union, like the United States, has a variety of early warning systems to alert it of a possible U.S. attack, but U.S. Department of Defense publications indicate that current Soviet launch detection systems provide poor, incomplete, or non-existent warning of submarine-launched missiles. The Soviet Union would receive warning of an attack not when the missiles are launched, but only when line-of-sight radars first detect warheads coming over the horizon, a quarter hour or less before impact. Thus it could be argued today that any U.S. SLBM, hard target capable or not, is destabilizing because of Soviet failures to develop adequate launch detection systems.*

But Department of Defense publications suggest that Soviet warning systems may be upgraded to include such capabilities by the end of the decade, which would then provide them with almost as much warning of an SLBM attack as of an ICBM attack. Thus, as long as both the U.S. and

* It should be noted that Soviet Yankee-class submarines, equipped with 1,300-nautical-mile range missiles, patrol near the U.S. coast. These missiles are potentially within less than 10 minutes flight-time of Washington and other U.S. targets on the East and West Coasts. Hence even with launch detection data, decision time in the United States today could be relatively short.

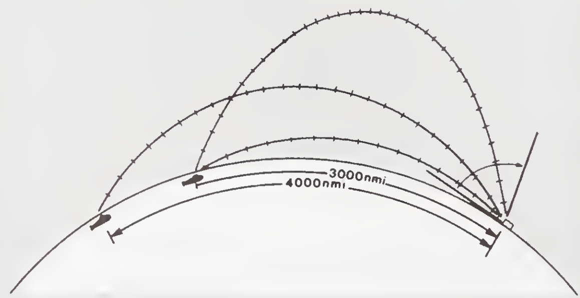
## SLBM Trajectories

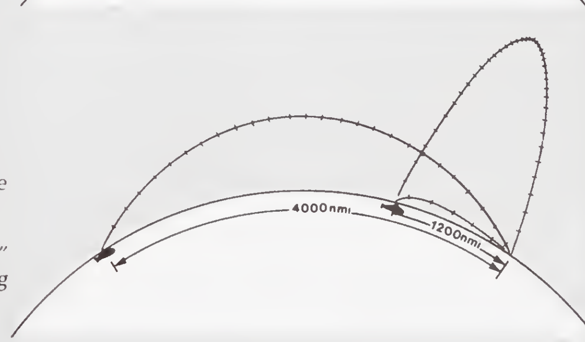
*A variety of trajectories for a submarine-launched ballistic missile like a Trident I or II are shown at right. The points along each trajectory are separated by 60 seconds of flight time. For example, the 4,000-nautical-mile (nm) trajectory has about 26 intervals, indicating a flight time of about 26 minutes from launch to target. Since the curves are calculated by assuming the missile instantaneously achieves the required velocity, adding about 2 minutes of flight time to any of the above curves gives an estimate of the approximate time of flight from breakwater to impact on target.*

*The 4,000-nm range trajectory shown above is called the "minimum energy" trajectory. It is the trajectory that results in a maximum range for a given achieved velocity.*

*Since the fully loaded missile can only achieve a certain velocity during boost, it must loft the warheads at an "optimal" angle to achieve maximum range. If the loft angle is larger or smaller than optimal, full range will not be achieved. At shorter ranges, the missile does not need to achieve as high a velocity to reach its targets. It is therefore possible to use this additional velocity to "loft" or "depress" the trajectory above or below the optimal trajectory. Lofting can be useful because warheads spend a longer time coasting toward targets, allowing for greater dispersal of the warheads and making it possible to attack widely separated targets. Depressing a trajectory also can be useful, since the warheads take less time to arrive at targets, reducing an enemy's warning and reaction time. The depressed curves for 3,000 nm and 1,200 nm ranges, for example, would take about 17 and 8 minutes, respectively, from missile breakwater to impact on target.*

*Such trajectories would be desirable for attacks that are designed to minimize an enemy's warning and reaction time. Warheads on severely depressed trajectories re-enter the atmosphere at small angles relative to those that re-enter from optimal ones. Thus, they travel long distances through the atmosphere before reaching the ground, and are subject to severe aerodynamic heating and dynamical interaction with the atmosphere. For this reason, it is very unlikely that a weapon system that has not been thoroughly tested under such conditions would be depended on for a critical nuclear mission. Neither the United States nor the Soviet Union has tested SLBMs on depressed trajectories, presumably because both recognize the provocation inherent in such tests.*




Soviet Union continue to emphasize long-range SLBMs and do not test them on depressed trajectories, which offer much shorter flight times (see box on SLBM trajectories), it seems unlikely that the problem of warning time will confront us with stability issues more fundamental than those raised by the Trident's counter-silo capability.*

### A Plausible Scenario

The question of the stabilizing or destabilizing effect of the Trident cannot be examined in isolation, however. To examine whether or not the Trident will create strategic imbalances as dangerous as some have argued, it is necessary to make some projections about the number, types, and capabilities of future U.S. and Soviet forces. Table 1 shows the postulated disposition of Soviet and U.S. silo-based forces from the late 1980s to the mid-1990s.

U.S. silo-based forces currently consist of 450 relatively inaccurate Minuteman IIs, each of which delivers a single powerful warhead, and 550 somewhat more accurate Minuteman IIIs, each of which delivers three warheads. (The large and aging

* It is important to distinguish between possible instabilities introduced by the shortness of warning time and those introduced by counter-silo capability. If SLBMs do not threaten central strategic forces, even if warning time is short, leadership still has an option to arrange for an orderly transition of decision-making authority. For instance, in the event of a loss of communication with leadership during a crisis, arrangements could be made for an alternate leadership group to take over national command responsibilities. The alternate national leadership could adopt, by prearrangement, a wait-and-see posture designed to determine whether or not an attack was the cause of the loss of communication. However, if the SLBMs (or other attacking systems) present a credible threat to central strategic forces, such arrangements do not buy either decision-making options or decision-making time.

Table 1. Possible U.S.-Soviet silo based forces—late 1980s to mid-1990s.

| | U.S. | | | U.S.S.R. | |
|---|---|---|---|---|---|
| | ICBMs | War-heads | | ICBMs | War-heads |
| MX | 100 | 1,000 | SS-18 | 308 | 2,464 |
| MMIII | 450 | 1,350 | -19 | 360 | 2,160 |
| MMII | 450 | 450 | -17/Equivalent | 152 | 608 |
| | | | -13/Equivalent | 60 | 60 |
| | | | -11/Equivalent | 520 | 520 |
| Subtotals | 1,000 | 2,800 | Subtotals | 1,400 | 5,812 |

Titan missiles are currently in the process of being retired and are not expected to be in service by 1987.) It is assumed for the sake of this article that the U.S. modernizes, following President Reagan's program, by replacing 100 Minuteman IIIs (by the end of 1988 or beginning of 1989) with the new and much more capable MX missiles, each of which delivers 10 warheads. For reasons determined at least in part by political constraints, all of these modern MX missiles will be located in a single deployment area within Warren Air Force Base.

Altogether, by the late 1980s to mid-1990s, the U.S. silo-based force will consist of 450 Minuteman IIs, 450 Minuteman IIIs, and 100 MX missiles. These 1,000 silo-based missiles will be capable of delivering 2,800 warheads against Soviet targets. Note, however, that 1,000 of these 2,800 warheads will reside on 100 MX missiles housed in Minuteman III silos, which can be attacked by today's Soviet ICBMs.

The number of Soviet silo-based missiles is assumed to remain constant at 1,400 (in accord with current Department of Defense projections). Department of Defense reports on Soviet ICBM development programs indicate no developments of the type that would precede a dramatic short-term reconfiguration of silo-based forces. It is therefore reasonable to assume that further investment in this increasingly vulnerable force will be limited to upgrades of existing systems, resulting in a ratio of multiple to single warhead missiles roughly similar to that which exists today.

The Soviets are developing two new solid propellant ICBMs, the SS-X-24, which carries about 10 warheads, and a smaller, mobile ICBM, the SS-X-25, which carries only a single re-entry vehicle. Although the "small" SS-X-25 is known to be mobile, it also could be used as a replacement for the aging SS-13 and SS-11 missiles. The "medium" SS-X-24 might replace the least capable Soviet multiple warhead missiles, the SS-17s. Thus, in the late 1980s to mid-1990s, the Soviet silo-based force will likely consist of about 1,400 silo-based missiles capable of delivering about 6,000 warheads.

Today, the Department of Defense states that 80 percent of the current Minuteman force could be destroyed if attacked two-on-one by Soviet SS-18 or SS-19 systems. It should be noted that *all* such projections are highly speculative, and are based on a host of untestable extrapolation procedures and assumptions (see inset on some of these uncertainties, page 51). On the basis of the best available test data and intelligence, however, no one can prove these assumptions to be incorrect. Since both Soviet and U.S. decision-makers want to have confidence that their forces are invulnerable, it is likely that they would not gamble that such calculations *might* be wrong.

It is therefore almost certain that both Soviet and U.S. decision-makers will continue to view incremental improvements in missile accuracy with some alarm. From the perspective of a U.S. decision-maker, by the late 1980s the Minuteman IIs and IIIs, as well as the not yet deployed MXs, may come to be regarded as *completely* vulnerable. Soviet leadership is likely to regard their silo-based force to be vulnerable as well.

The Department of Defense has not reported any projections of Soviet vulnerabilities to the public. However, as noted previously, since profound technical uncertainties would underlie any such projections, even if a Department of Defense analysis fully utilized available technical and intelligence information, such projections could well be misleading. Thus, the calculations presented here should be considered as credible (but not more so) as any that might be done within the Department of Defense.

A range of projections of U.S. counter-silo capability in late 1988 or 1989, before the deployment of Trident II missiles begins, is shown in Figure 4. Since each side will want to be as certain as possible of the reliability of its nuclear strategies, both sides will be conservative in estimating the strength of their offensive forces and the effectiveness of efforts to protect these forces. As the hardness of missile silos and the accuracy and reliability of missiles under wartime conditions are uncertain, each side probably would have different assessments of the outcome of a counter-silo attack.

Thus, when the Soviets assess the consequences of a first strike against their own forces using reasonable assumptions, they assume a silo hardness that is less than that assumed by the United States. In addition, the Soviets may also assume that U.S. missiles are more reliable and more accurate than the United States itself assumes. Hence, Soviet and U.S. projections of the outcome of a first strike could well be quite different.

Using a plausible but arguable set of assumptions, the Soviets might therefore project that a U.S. first strike using MX and Minuteman III will reduce their force from about 6,000 warheads to one or two hundred, while the U.S. might assess the same attack as resulting in about 1,000 remaining deliverable Soviet warheads (Figure 4).

A striking possibility is shown as the third bar in Figures 4a and 4b. In this case, the attack outcome against Soviet silos is projected by assuming that no MX missiles are used. From the perspective used in assessments of strategic stability, such a circumstance could arise if the Soviets successfully executed an extremely limited attack using 100 to 200 warheads against MX silos only. For a Soviet investment of 2 or 3 percent of their available silo-based warheads, they would be able to ride out any U.S. response and be in a "strategically superior" position.

# *Silo Strength and Missile Accuracy*

***H**igh value Soviet MIRVed missiles are assumed to be in upgraded, "super-hardened" silos, able to survive the many effects of nuclear detonations (blast, heat, ground motion, nuclear radiations, electric field effects, and so on) including a shock wave of 4,000 pounds per square inch (psi). Less valuable single warhead missiles are assumed to be housed in less expensive, "softer" silos, able to withstand effects equivalent to 1,000 psi. Differences in silo hardness estimates made by U.S. and Soviet planners are, for simplicity, accounted for in their choices of missile accuracy. For example, the U.S. planner believes MX has an accuracy of 400 feet against the Soviet 4,000 psi silo, while the Soviet estimates that MX accuracy is instead 300 feet. In terms of probability of destruction, the U.S. planner could make the equivalent assumption that MX has an accuracy of 300 feet, but the upgraded Soviet silo is nine or ten thousand psi hard, rather than 4,000 psi hard. Estimates for the Trident II are based on scaling from the MX and Minuteman III.*

| | U.S. Planners "View" | | | Soviet Planners "View" | | |
|---|---|---|---|---|---|---|
| **Missile System** | **System Reliability*** | **CEP(ft)**** | **Yield (kilotons)** | **System Reliability** | **CEP(ft)** | **Yield (kilotons)** |
| **MX** | .9 | 400 | 300Kt | .95 | 300ft | 600 |
| **TRIDENT II** | .9 | 400 | 300Kt | .95 | 300ft | 600 |
| **MMIII (MK12A)** | .9 | 1,000 | 300Kt | .95 | 600ft | 300 |
| **MMIII (MK12)** | .9 | 1,000 | 150Kt | .95 | 600ft | 150 |

| | U.S. "View" Damage Expectancy | | | Soviet "View" Damage Expectancy | | |
|---|---|---|---|---|---|---|
| | (Percent chance of a given missile destroying a Soviet silo) | | | | | |
| **Silo "Hardness" (psi)** | **4,000** | **2,000** | **1,000** | **4,000** | **2,000** | **1,000** |
| **MX/TRIDENT II** | 77 | 86 | 90 | 95 | 95 | 95 |
| **MMIII (MK12A)** | 24 | 35 | 49 | 55 | 71 | 84 |
| **MMIII (MK12)** | 16 | 24 | 35 | 40 | 55 | 71 |

*** System reliability is the probability that everything in a system will function and the warhead will arrive in the vicinity of a target.**
**** CEP is the radius within which half of the warheads that arrive in the vicinity of the target will fall.**

This pathologically attractive option comes about for the following reason: The 100 MX silos destroyed in the extremely limited Soviet attack contain the 1,000 most capable U.S. silo-based warheads. Although the remaining 900 unstruck Minuteman boosters still contain perhaps two thirds of the available U.S. silo-based warheads, the missiles are far less accurate, and hence each remaining warhead has a far smaller probability of destroying a Soviet silo than would an MX warhead. Thus, even though the remaining U.S. silo-based force would be left with nine-tenths of its missiles and two-thirds of its warheads, a U.S. response against Soviet silo-based forces to "redress" the imbalance or punish the Soviets, would still result in the survival of a very large part of that force (the Soviet planner would project possibly 2,500 surviving warheads, the U.S. planner 4,000).

Thus, even if escalation were to follow, the successful execution of a remarkably limited attack of perhaps 100 to 200 warheads, involving the launch of as few as 10 to 20 multiple warhead SS-18 missiles, might guarantee the Soviets enough silo-based forces to rapidly attack U.S. silos, command centers, and industrial targets should the crisis intensify.

From the point of view of a desperate Soviet

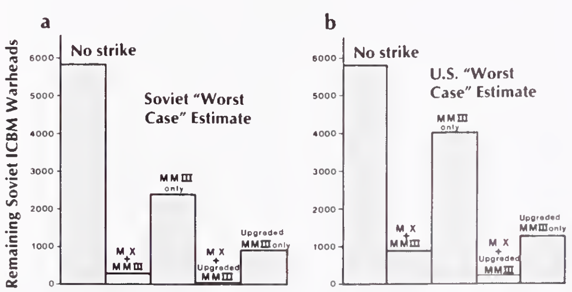



*Figure 4. The two bar charts above show the predicted outcome of a U.S. first strike against the Soviet silo-based force postulated in Table 1, as viewed by Soviet (a) and U.S. (b) planners. The assumptions used by the author for the above calculations are summarized in the box above.*

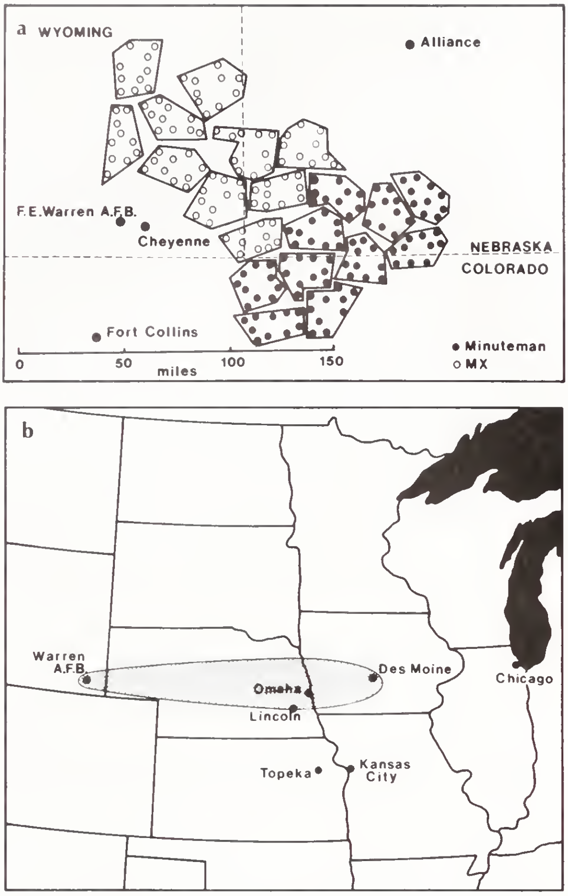



*Figure 5. a) A map of Warren Air Force Base, which is located in Wyoming, Colorado, and Nebraska. At this site, 100 MX missiles will replace 100 Minuteman IIIs. b) Possible fallout pattern from a limited attack on MX silos at Warren Air Force Base. The pattern assumes a 15 mile per hour (mph) westerly wind at the time of a 100- to 200-megaton attack. Variations in wind conditions could result in dramatically different results. If, for instance, the wind carried the fallout cloud slightly to the south, it would reach Lincoln, Nebraska, about 25 hours after the attack. Although radioactivity would diminish rapidly, if individuals did not evacuate the area or seek shelter, 7 to 8 hours exposure to the radiation would be sufficient to require hospitalization; within 20 hours a lethal dose would result. If all conditions were the same except that the prevailing wind happened to be 25 mph, then the cloud would arrive at Lincoln sooner and initial radiation levels would be much greater; one hour of exposure would result in a need for hospitalization, and two hours' exposure would cause certain death. If these unusually high winds instead carried the fallout toward Chicago, lethal levels of fallout could even result there. Thus, although the attack on the MX would be very limited by the relative measures implied in the concept of strategic stability, the consequences of the attack in absolute human terms would be highly unpredictable, varying only in degrees of horridness. Within the stippled area unprotected people would receive a lethal dose of radiation within a week of the attack.*

decision-maker a limited attack with such high-payoff, aimed only at preserving Soviet military capabilities, might well be worth considering. After all—it might be argued—such a limited anti-ICBM attack would be far less provocative than one involving 1,000 to 2,000 warheads, and would therefore be much less likely to provoke a full-scale U.S. response with remaining bomber and submarine forces. Furthermore, all the MX-filled Minuteman silos will be located at a single location in a sparsely settled area of the central United States (Figure 5). Hence, a desperate and exhausted Soviet leadership might well reason that information provided by U.S. early warning systems would be adequate for an accurate U.S. assessment of the limited nature and intent of the attack.

But such a limited Soviet attack against the MX would deny the United States the ability to decisively destroy the Soviet silo-based force. Thus, the U.S. incentive to launch the MXs first, or in response to any limited Soviet action, would be very great, and the Soviet incentive for such an attack would be perhaps greater yet. This circumstance is as unambiguously destabilizing as any yet postulated in the strategic debate.

Moreover, there is good reason to believe that the consequences of such a limited Soviet attack would not be viewed with equanimity by U.S. leadership (see Figure 5). There is, of course, good reason to believe that this also would be understood by Soviet leadership. In addition, the Soviets would have to gamble that the U.S. would not launch its MXs while withholding Minuteman in response to the limited attack. If this occurred, the Soviets would be forced to choose between losing most of their silo-based forces, or launching them, perhaps guaranteeing a complete exchange of both U.S. and Soviet ICBMs. Once ICBMs had been launched by one or both sides, a wholly new range of still more terrifying actions would likely follow, including a quick (or even simultaneous) launching of bomber forces, SLBMs, and theater nuclear systems.

This circumstance points to an important fact that is often ignored in both strategic planning and stability analyses: the projected improvements in the strategic offensive capabilities of both U.S. and Soviet SLBMs and ICBMs offer no hope of definitively preventing socially and militarily mortal responses to a preemptive attack.

### The Effect of the Trident

The pathological instability created by the deployment of 100 MX missiles in silos at Warren Air Force Base will be the situation in late 1988 or early 1989, before large numbers of Trident II warheads become available. In late 1989 or early 1990, the first Trident IIs will be deployed. Shortly thereafter, they will exist in sufficient numbers to offset this extreme instability.

The rapid introduction of Trident II submarines comes about because newly constructed Trident submarines can immediately accommodate Trident II missiles, and older Trident I carrying submarines can be converted during their first major overhaul to carry Trident II (Figure 6). Thus, in 1988 the first Trident II capable submarine will become available as a test platform for launches of the Trident II missile, and deployment of operational missiles will begin at a rapid pace at the end of 1989 or the beginning of 1990.

From the point of view of the Soviet decision-maker who has the objective of preserving Soviet silo-based military and retaliatory capabilities, the very limited attack against MX postulated previously is only interesting insofar as it meets its objectives. By 1992 or 1993, assuming the high deployment rate estimated in Figure 6 is correct, sufficient numbers of "MX-equivalent" Trident II warheads will diminish the attractiveness of an anti-MX attack. Thus, the attack against the 100 MXs only remains attractive for a period of three to five years, between perhaps late 1988 and 1992 to 1994.

After 1993 or 1994, since the U.S. could redress any strategic imbalance by destroying Soviet ICBMs with Trident II warheads, even a full-scale counter-silo attack against all U.S. land-based systems would cease to preserve Soviet ICBMs. Thus, almost commensurate with the removal of the pathological instability created by the MX deployment, Trident II itself creates a destabilizing situation by presenting a threat to Soviet silo-based forces.

There are, however, two closely related but distinct reasons why Trident II, according to stability arguments, is less strongly destabilizing than MX; one is because of the extraordinary vulnerability of the MX, the other due to the extraordinary *in*vulnerability of Trident. Consideration of these two reasons leads to the following observations:

- *The introduction of Trident II missiles, while representing a serious and increasingly destabilizing threat to Soviet silo-based forces, would negate the benefits of a limited strike against U.S. silo-based MX missiles.*

- *While Trident II might force the Soviets to plan to launch their silo-based forces rapidly, the system is so impervious to the affects of a Soviet preemption that the Soviets could not even hope to reduce, much less eliminate, U.S. ability to meet any identifiable counter-military, counter-silo or assured destruction objectives. Under these conditions, they would have no incentive to strike first. Although, as already noted, Soviet preparations to launch rapidly if the U.S. tried to strike first would certainly increase the likelihood of accidental or inadvertent war.*

### Other Factors

This raises another question. Will the Trident II drive Soviet decision-makers to see themselves as trapped in a dangerous use-or-lose circumstance? In fact, evidence is already emerging to suggest that this may not be the case.

The Department of Defense has reported that the Soviets have recently taken steps that indicate a greatly increased interest in long-range strike aircraft and air-launched cruise missiles (Figure 7). An entirely new variant of the Bear bomber (the Bear H), which probably is a long-range cruise missile carrier, has been introduced.* This marks the first new production of a strike version of the Bear airframe in more than 15 years. It also is known that

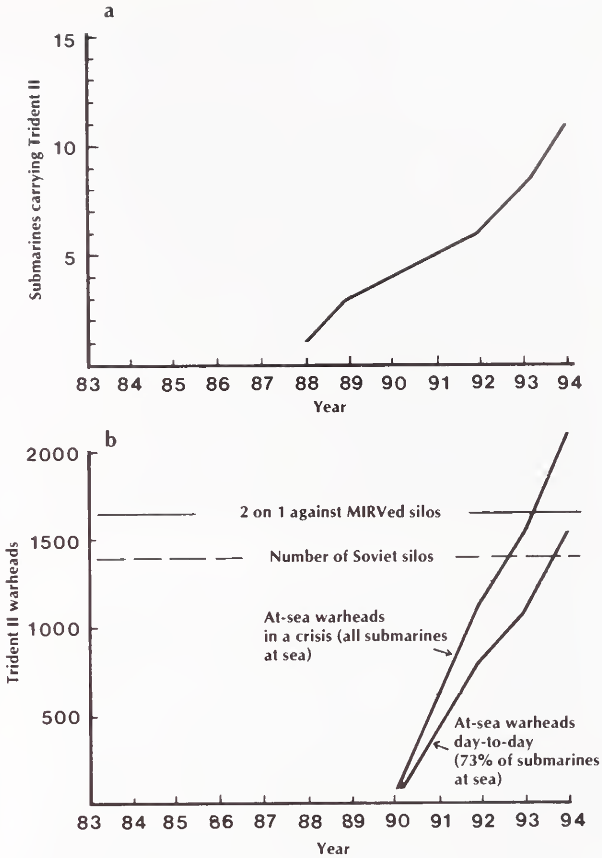



*Figure 6. a) The number of Trident II carrying submarines by year, as reported by the Congressional Research Service. b) The author's estimates of the number of at-sea warheads available on a day-to-day basis and in a crisis. The lines across the top of the graph indicate the number of warheads needed to attack all Soviet silos and to send two warheads against all MIRVed silos.*

the Soviets are developing a long-range heavy bomber, the Blackjack, which appears similar to the U.S. B-1B bomber, but is larger. This aircraft is projected to become operational in 1987.

Assuming a modest production rate of one Bear H a month, followed by a similar rate of production of Blackjacks starting in 1988, the Soviets could easily achieve a force of some 90 Bear H and 60 Blackjack bombers by 1993. If the Bear H carries only 8 long-range air-launched cruise missiles and the Blackjack carries only 16, then by 1993 the Soviets could deliver more than 1,700 cruise missile warheads against the United States with these bombers alone. If for some unforeseen reason the Blackjack development program suffers serious

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* The Soviet Bear aircraft is a huge, high-speed and high-endurance four turboprop aircraft that has been in production for more than 30 years. In addition to several strategic strike versions of the Bear, there also are distinct configurations for maritime strike, for over-the-horizon target acquisition in support of naval forces, for long-range maritime reconnaissance, and for long-range antisubmarine warfare.

delays or failures, Bear H production might, for instance, be doubled in 1988. By 1993, even if no Blackjacks are produced, this would result in a bomber force capable of delivering more than 1,400 air-launched cruise missiles against the United States.

Projections published by the Congressional Research Service of Soviet SLBM warheads show a growth in the number of deliverable warheads over the next decade, mainly because of the introduction of additional multiple independently-targetable re-jentry vehicle (MIRV) missiles on a growing number of modern, quiet, MIRV carrying submarines of the Typhoon class (Figures 1 and 2). The projections indicate that the Soviets could have between 4,000 and 5,000 submarine delivered ballistic missile warheads, with possibly 2,000 of these warheads on exceptionally survivable ultra-quiet submarines by the early 1990s. Even if the Soviets could only deploy half of these forces in a crisis, then on the order of 2,000 warheads would be available for retaliation against the United States should war occur.

It is clear that no properly informed U.S. decision-maker, unless stressed to the point of extreme irrationality, would be willing to accept the consequences of these forces being unleashed on the United States. It is equally unlikely that informed Soviet leadership would be willing to accept a similar fate for their country. Thus, the question comes back, as it usually does, to what kind of measures are really useful in reducing the likelihood of a nuclear war that everyone wants to avoid.

The vulnerability of Soviet silo-based forces is not just the product of U.S. accuracy improvements, it is also a self-inflicted vulnerability as the result of poor Soviet military planning. While concern about the destabilizing possibilities of highly accurate ballistic missiles is understandable, it is also true that both the United States and the Soviet Union have had options to deploy less vulnerable systems. The United States has, with all its alleged domestic political problems, wisely developed diversified forces. These forces, because they are not use-or-lose, greatly reduce the technical demands for disruption-free communications and early warning systems. They also are greatly forgiving of errors of judgment, providing decision-makers with assets that need not be committed rapidly, massively, and irrevocably. The MX is, unfortunately, an exception to this wise pattern.

For these reasons, the development of much more capable and diversified Soviet strategic nuclear forces should not necessarily be viewed with alarm. If the Soviets do in fact successfully diversify their forces, then their dependence on vulnerable silo-based ballistic missiles would cease. Under these conditions Trident II would cease to have any destabilizing effects. These developments may therefore present important diplomatic opportunities in the 1990s for negotiated reductions or the elimination of destabilizing silo-based forces. If this is

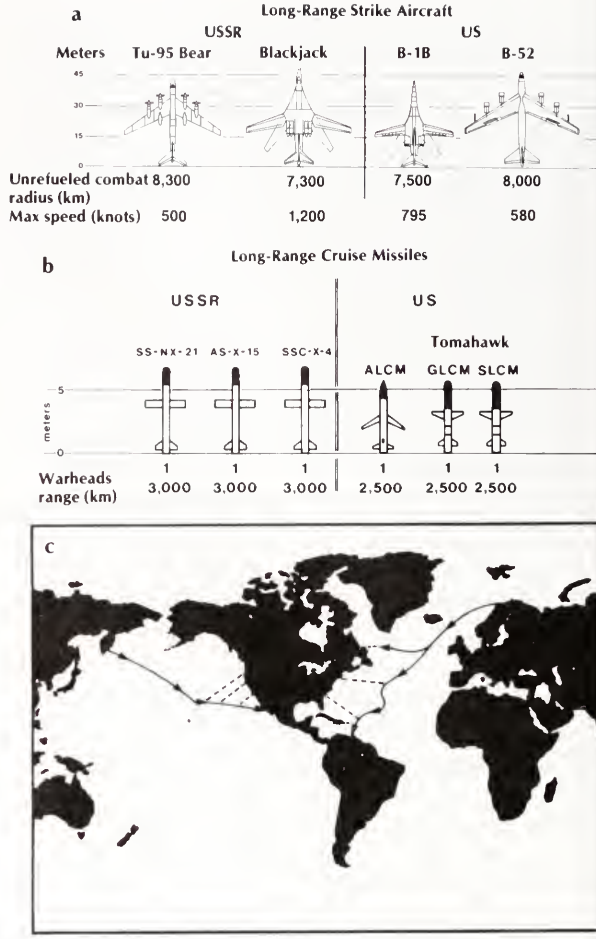


*Figure 7. a) U.S. and Soviet long-range strike aircraft. The extremely capable Soviet Bear bomber, first seen by the West in about 1954, could be the mainstay of a greatly expanded Soviet bomber force, even into the 21st century. b) Armed with perhaps seven or eight of the AS-X-15 air-launched cruise missiles, the Bear could stand-off thousands of kilometers from the United States and launch its weapons. c) The great range of this durable and capable turboprop, in combination with its 3,000-kilometer-range cruise missiles, would permit the Soviets to fly circuitous routes (solid lines) to launch points for hard-to-detect cruise missiles (dashed lines).*

what the future holds, the result will almost certainly be a world that is safer for all.

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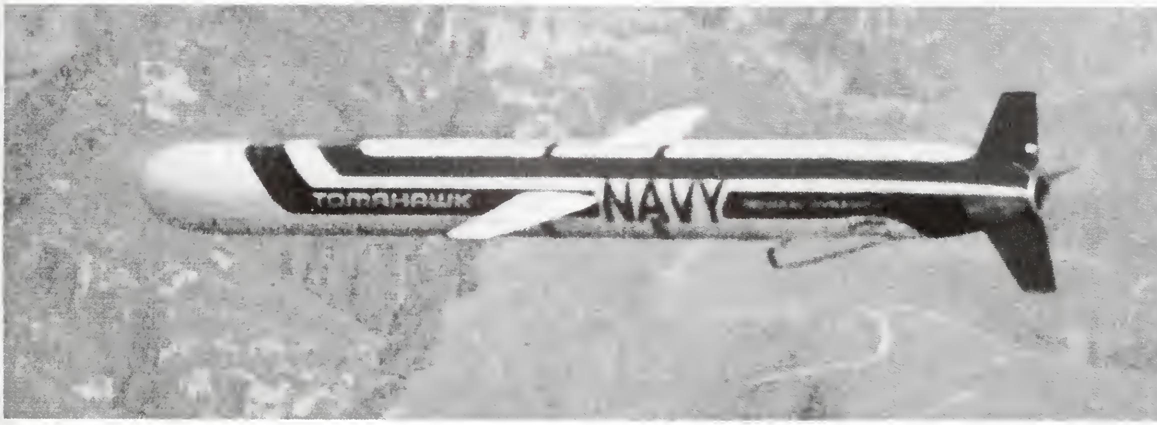
# The Tomahawk




# Nuclear Cruise Missile:

## *Arguments For and Against*

### by Jeffrey S. Duncan

The controversy surrounding big-ticket weapons systems such as the MX has obscured the importance of the cruise missile, which many consider the technological innovation that will most affect offensive military firepower in the 1980s. Current Reagan Administration plans call for the procurement of 9,000 cruise missiles during the next decade, some 4,000 of which will be stationed aboard approximately 180 U.S. Navy surface ships and attack submarines. Nearly 800 of these sea-launched cruise missiles (SLCMs) will be armed with 200-kiloton nuclear warheads—each 14 times more powerful than the bomb that destroyed Hiroshima.

In 1984, Congressional concerns about the Reagan Administration's failure to come up with a proposal for banning or strictly limiting nuclear SLCMs prompted calls for restrictions on their deployment. In the House of Representatives, the Defense Authorization Bill was amended to ban funding for the assembly or deployment of nuclear SLCMs until either the Administration could come up with a satisfactory way to verify the differences between nuclear and conventional SLCMs or the Soviets deployed their new long-range nuclear land-attack SLCM. Though the Senate rejected this approach, it urged inclusion of SLCMs in all future arms control negotiations with the Soviets, and successfully pressed the Navy to accept intrusive, on-site inspections as a way to ease verification of nuclear SLCM limitations.

Given the Reagan Administration's continuing opposition to a moratorium on nuclear SLCM deployments and the weapon's de facto exclusion from arms control proposals, Congressional pressures to halt or restrict further nuclear SLCM deployments are likely to continue.

**Background**

Cruise missiles—small, unmanned jet aircraft armed with either conventional or nuclear warheads—have been part of U.S. and Soviet arsenals throughout the post-World War II period. The Soviets placed greater emphasis on cruise-missile systems at first, because they lacked carrier-based aircraft capable of attacking U.S. warships. Throughout the 1960s and 1970s, the range of Soviet weapons remained short, and their accuracy fairly poor.

Early U.S. cruise missiles were large, unreliable, and, until the 1970s, notoriously inaccurate. However, U.S. interest in cruise missiles increased with the advent of new technologies and a convergence of political calculations—a desire for "bargaining chips" to use in arms-control negotiations, a need to appease critics of both Strategic Arms Limitations Talks (SALT) I and SALT II by showing our willingness to pursue new technologies not covered by the treaties, and a fascination with the military potential and relatively low cost of the cruise missile.

Ironically, the armed services originally opposed development of the cruise missile. They feared it would compete for scarce funds with favorite weapon systems. The Air Force was concerned that development of a long-range, air-launched cruise missile (ALCM) would undermine its rationale for the B-1 bomber; the Navy feared that, since SLCMs could be placed on any ship and be used against targets at sea or on land, SLCMs would compete with big aircraft carriers; and the Army worried that ground-launched cruise missiles (GLCMs) would compete with artillery on the battlefield and with the other services' existing "tactical" and "strategic" weaponry, draining resources from the conventional forces.

Despite the reservations of the military, Defense Secretary Melvin Laird, Secretary of State Henry Kissinger, and, later, Defense Secretary Harold Brown found the cruise-missile option attractive. Between 1970 and 1980, under the stewardship of these men, the cruise-missile program moved from the drawing board to engineering development to actual flight-testing, while remaining largely outside the purview of ongoing arms-control negotiations. As work on the new missiles progressed, interest in the military potential of cruise systems and protecting the growing U.S. lead in the field overcame the original desire to use the cruise missile as a bargaining chip. In fact, during SALT II the United States resisted Soviet efforts to ban deployment of long-range nuclear-armed cruise missiles. The United States accepted inclusion of ALCMs in the overall SALT II ceilings, but resisted attempts to prevent the deployment of new GLCMs and SLCMs, finally agreeing to a three-year ban on deployment that would not interfere with research and development efforts nor alter the Pentagon's timetable for cruise-missile deployment.

The Reagan Administration, while informally abiding by unratified SALT II, considers the limitations on GLCMs and SLCMs to have lapsed—since they were contained in a protocol to the treaty set to expire in December of 1981. This Administration began deploying GLCMs (along with Pershing II ballistic missiles) in the fall of 1983, prompting a Soviet walkout from talks on limiting intermediate-range nuclear forces and a Soviet suspension of strategic arms talks. Though the Reagan Administration had indicated "everything is on the table" during those negotiations, it opposed including SLCMs in either Intermediate Nuclear Force (INF) or Strategic Arms Reduction Talks (START), citing the difficulty of verifying SLCM limitations. The Administration began deploying nuclear SLCMs in June of 1984.

Negotiations between the United States and the Soviet Union have resumed in Geneva. However, it is uncertain whether nuclear SLCMs are on the agenda, or whether the United States has a proposal for a ban or strict limitations on these weapons. In its most recent Arms Control Impact Statement, the Reagan Administration expressed skepticism about the possibility of SLCM limits, noting, "With regard to potential future arms control agreements, small mobile systems such as cruise missiles are likely to present difficulties for verification."

**Description and Analysis**

The "Tomahawk" Sea-Launched Cruise Missile Program has three parts: the Tomahawk Anti-Ship Missile (TASM), the Tomahawk Conventional Land-Attack Missile (TLAM-C), and the Tomahawk Nuclear Land-Attack Missile (TLAM-N). Of a total program budget of some $13.8 billion (in 1977 dollars, the year the program began), two-thirds is reserved for the procurement of conventionally armed SLCMs (2,600 "land-attack" missiles and 600 "anti-ship" missiles); $1.8 billion is reserved for the nuclear-tipped version (about 760 nuclear land-attack missiles). A separate, classified account is reportedly earmarked for research and development of an advanced "Stealth" SLCM that will eventually serve as a follow-up to the Tomahawk.

**The Conventional Anti-Ship Missile (TASM)—**

The TASM is a conventional missile for destroying enemy navies and keeping open sea lanes in time of war. With a range of about 300 miles and a 900-pound high-explosive conventional warhead, the TASM extends the standoff attack capability of U.S. surface ships and submarines by a factor of four or five. These missiles became operational aboard attack submarines in November, 1983, with the first operational deployments on surface ships in June, 1984. Outside analysts note that vessels armed with the TASM could threaten an enemy vessel within 200,000 square miles, and could prevent the movement of enemy ships through channels less than 500 miles wide.

Similar—but less sophisticated—anti-ship cruise missiles have been used since 1967, when an Egyptian patrol boat used a Soviet-made SLCM to sink the Israeli destroyer *Elath*. TASM supporters hope that TASMs will endow U.S. surface warships similarly—a capability previously limited to carriers with bomb-laden aircraft.

Total program acquisition cost for the TASM is estimated at $1.9 billion. The fiscal-year 1986 request is for about $290 million for 97 missiles (Table 1).

**The Conventional Land-Attack Missile (TLAM-C)—**

Like the TASM, the TLAM-C is a conventional missile deployed on ships; unlike TASM, the TLAM-C is for use against land-based targets such as airfields, communications centers, and industrial complexes. Already deployed on the battleships *New Jersey* and *Iowa*, the TLAM-C allows ships to project power ashore, from distances that previously would have required carrier-based aircraft.

The TLAM-C ranges up to 700 miles, can carry either a single 1,000-pound warhead or multiple small submunitions (bomblets), and has an accuracy approaching 30 feet. It would be suitable for use against the Soviet Union, whose sophisticated air defense system makes manned bomber attacks very costly; it also would be adaptable for use in the Third World. For example,

Table 1. Planned U.S. SLCM procurements.

| | FY80 | FY81 | FY82 | FY83 | FY84 | FY85 | FY86 | FY87 | Planned Total |
|---|---|---|---|---|---|---|---|---|---|
| TLAM-N | – | – | 4 | 28 | 76 | 75 | 118 | 83 | 758 |
| TLAM-C | 3 | 25 | 16 | 0 | 0 | 30 | 34 | 127 | 2,643 |
| TASM | 3 | 25 | 41 | 23 | 48 | 75 | 97 | 120 | 593 |
| Total SLCM | 6 | 50 | 61 | 51 | 124 | 180 | 249 | 330 | 3,994 |

Sources: U.S. Navy, Congressional Research Service.

Planned SLCM Deployments
(Cumulative ships armed with Tomahawk by year)

| | FY83 | FY84 | FY85 | FY86 | FY87 | FY88 | FY89 | FY90 | FY91 | By 1993 | By mid-90's |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Battleships | 1 | 1 | 2 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| Destroyers | 1 | 2 | 4 | 7 | 9 | 11 | 21 | 22 | 29 | 45 | 60 |
| Cruisers | 0 | 0 | 2 | 4 | 8 | 12 | 14 | 17 | 14 | 24 | 27 |
| Submarines | 6 | 12 | 18 | 32 | 42 | 56 | 65 | 79 | 88 | 92 | 106 |
| Total | 8 | 15 | 26 | 46 | 62 | 82 | 104 | 100 | 131 | 165 | 197 |

Sources: U.S. Navy; Congressional Research Service.

the conventional Tomahawk could easily have been used against Syrian anti-aircraft sites in Lebanon in 1983, rather than using A-6 attack planes (which resulted in the lost life of one U.S. pilot and the capture of Lt. Robert Goodman). A few prototype TLAM-Cs were deployed on the *New Jersey* beginning in 1983, and plans call for operational deployment of the TLAM-C to begin in 1986.

The total program acquisition costs for the missile are estimated at $6.7 billion. Approximately $120 million in procurement funding, for 34 conventional missiles, has been requested for fiscal year 1986.

### The Nuclear Land-Attack Missile (TLAM-N)—

The TLAM-N, the sole nuclear-tipped SLCM, is by far the most controversial of the various SLCMs, by virtue of its potential for use in multiple situations, ranging from a limited nuclear conflict to a prolonged nuclear war. The TLAM-N was developed to provide the U.S. Navy with both a limited nuclear warfighting capability and a "strategic reserve." By dispersing U.S. nuclear capabilities among a much wider range of naval vessels, the U.S. gains in survivable warheads and complicates Soviet naval-targeting strategies.

The TLAM-N has a range of up to 1,500 miles, and can carry a 200-kiloton nuclear warhead to within 100 to 300 feet of its intended target—roughly comparable to the high accuracy of the planned Trident II (D-5) SLBM. Unlike the Trident II, however, the nuclear Tomahawk travels at a slow, subsonic speed of about 550 miles per hour, making it poorly suited for use against targets that would have to be destroyed quickly in a "counterforce" strike, such as ICBM silos or command and control bunkers. For this reason, the nuclear Tomahawk probably would be used either in a "limited" nuclear war against Soviet land targets, such as military bases, seaports, and airstrips, or in a follow-up strike against targets that survived an initial U.S. nuclear attack.

Deployment of the TLAM-N on surface ships and attack submarines began in June of 1984. According to the Navy, as of the end of fiscal year 1984, a total of 12 submarines and two destroyers were TLAM-N capable. Total program acquisition costs for the nuclear Tomahawk are estimated at $1.8 billion (excluding a classified amount for nuclear warheads). For fiscal year 1986, approximately $300 million has been requested for 118 nuclear SLCMs.

### Soviet Cruise Missile Capability

The Soviets began developing their cruise missile capabilities in the late 1940s. During the 1950s and 1960s, they deployed air, ground, and sea-launched cruise missiles with both conventional and nuclear warheads. These Soviet SLCMs were fairly primitive in nature and designed primarily for use against sea- rather than land-based targets.

According to the Department of Defense (DoD), some 215 Soviet ships have nuclear cruise missile capability, with seven different types of nuclear-capable SLCMs in service. Only two of these missiles (the SS-N-3 and an improved version known as the SS-N-12) could attack land targets with nuclear warheads (the other nuclear SLCMs are anti-ship weapons). The first of these nuclear-tipped, land-attack Soviet SLCMs (the SS-N-3) was operationally deployed in 1962. Both the SS-N-3 and the SS-N-12 are large, rather primitive missiles armed with 350-kiloton nuclear warheads; they are believed to be meant for use against population centers, since their poor accuracy and short range (250 miles) ill suits them for use against many military targets.

In 1981, the Soviets began flight-testing a new and far more capable nuclear land-attack SLCM. Known as the SS-NX-21, this new SLCM is very similar to our Tomahawk: like ours, it carries a 200-kiloton nuclear warhead and has a range of about 1,500 miles; it has about the same speed as ours, and can be fired from regular torpedo tubes. However, neither its estimated accuracy (about 600 feet as opposed to 100 to 300 feet) nor its guidance system is believed to be as sophisticated as the Tomahawks'—although the missile is believed accurate enough to destroy hardened military targets.

Reportedly, the new missile completed its

flight-testing program, but though the U.S. Navy expected it to become operational in 1984, apparently it has not. Recent expectations are that the SS-NX-21 will be deployed on one or more classes of Soviet submarines later this year. There are no indications of plans for deploying this missile on surface vessels.

A second nuclear land-attack SLCM, the SS-NX-24, is under development, with initial flight tests expected to begin onboard a converted Yankee-class submarine. The SS-NX-24 is physically much larger than the SS-NX-21, has a greater range, and probably will be capable of reaching supersonic speeds. It is expected to become operational within the next two years.

According to 1985 testimony by U.S. Navy Intelligence Chief Admiral John L. Butts, "The SS-NX-21 probably is intended primarily for theater applications, but also likely would be employed for strikes against U.S. targets such as command, control, and communications facilities and naval bases." In previous testimony, Admiral Butts stated, "The other new missile [the SS-NX-24] ... likely is intended to cover targets such as major industrial centers, key military facilities, and vital $C^3$ [command, control, and communications] sites in the U.S."

The U.S. Navy reported that the Soviets are working on stealth technologies for their SLCMs, and "could deploy some retrofitted ... cruise missiles this decade whose radar signatures will be reduced substantially." Such missiles would be difficult to detect and locate, particularly when flying at low altitudes. For this reason, Reagan Administration officials are concerned that these new Soviet SLCMs might "negate" current plans for protecting the U.S. bomber force, since they could arrive before U.S. strategic bombers had a chance to escape the runway. To improve detection and tracking of Soviet SLCMs, the U.S. is researching infrared sensors, but they are not expected to be deployed until the early to mid-1990s.

### Arguments For the Nuclear SLCM

Supporters of the nuclear Tomahawk argue that it would be low-cost and highly effective, and would provide an additional "strategic reserve." Deployment of these weapons on ships, proponents assert, vastly upgrades the Navy's ability to deter Soviet attacks by threatening retaliation, and by enhancing ships' ability to attack Soviet targets ashore. Proponents argue that the nuclear Tomahawk is not inherently destabilizing because its slow speed prevents its being perceived as a first-strike weapon. Major points in the argument for the nuclear SLCM are as follows:

**1. Increased flexibility and effectiveness—**
With the deployment of the nuclear Tomahawk, proponents note, the Navy will grow from a fleet centered on 14 nuclear-capable aircraft carriers to a fleet with more than 180 potential nuclear-strike platforms. This force will be able to threaten areas of the Soviet Union not now targetable by naval forces, stretching Soviet air defenses beyond their capabilities. Proponents also contend that the new SLCM force will provide flexibility in Third World areas facing a Soviet threat—in the Persian Gulf, for instance, where we should have the flexibility to respond to a Soviet incursion with forces more effective than our present conventional weapons and troops, but less provocative or destructive than a strategic nuclear strike.

**2. Improved survivability—**
By deploying the nuclear Tomahawk on cruisers, destroyers, and battleships, proponents argue that we disperse our nuclear retaliatory threat so widely that any Soviet attempt to attack our sea-based deterrent would be doomed.

**3. Strategic reserve—**
Proponents also argue that nuclear-armed SLCMs, especially when deployed on submarines, will provide a credible and survivable nuclear arsenal (a strategic reserve) that could be used in a limited nuclear conflict against targets of naval interest (such as ports or naval airbases) or in a strike against military or industrial targets in Eastern Europe, the Soviet Union, or elsewhere. Such a capability would be particularly useful in a protracted nuclear conflict, when other nuclear forces already had been expended.

**4. Low cost—**
Supporters of the nuclear SLCMs point out that they are the least expensive nuclear deterrent yet developed. Supporters assert that the $3 million per missile price tag for the Tomahawk program is virtually nothing to pay for a weapon that secures our second strike capability and augments our strategic reserve—especially when compared to other strategic programs (such as the MX, which will cost more than $70 million per missile).

**5. Soviet SLCM threat—**
Supporters of the nuclear Tomahawk argue that the impending Soviet deployment of new nuclear SLCMs (the SS-NX-21 and SS-NX-24) makes it essential for the United States to move ahead with our own nuclear SLCM program.

While the Soviets admittedly have long had nuclear SLCMs, their new missiles pose a much greater threat to the United States than any previously deployed: their greater range, speed, and accuracy allow the Soviet Navy to target U.S. tactical and strategic assets from a safe "standoff" distance. To deter the Soviets from ever using these weapons, the United States must similarly threaten the Soviet Union: if the Soviets know that any use of their nuclear SLCMs could provoke a U.S. response in kind, they will have few incentives to initiate such an exchange.

While proponents of the Tomahawk concede that it might have been preferable had both sides chosen not to deploy these new weapons, they note that the Soviet Union—and not the United States—"started" the SLCM race, and assert that it is too late to put the nuclear SLCM genie back in its bottle. Proponents hold that the pace of Soviet SLCM development indicates a commitment to the exploitation of cruise missile technologies, and claim it would be naive to expect a unilateral U.S. halt of the nuclear Tomahawk program to lead the Soviets to abandon their programs.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### The Case Against the Nuclear SLCM

Opposition to nuclear SLCMs has been driven by questions on the arms control implications of SLCMs' deployment, and by doubts over the weapon's actual military utility. Underlying these arguments is a fundamental concern—that deployment of this weapon is a major step away from mutual deterrence, and a major step toward the adoption of highly destabilizing "warfighting" and "first strike" strategies.

**1. First strike capability—**
Opponents of nuclear SLCMs argue that perhaps the most dangerous implication of the new weapon is a little-discussed one: that, by serving as a new "strategic reserve," SLCMs free up our existing SLBMs from their second-strike retaliatory mission, making them available as a first-strike force against "hard" Soviet military targets.

Opponents note that as SLBMs (such as the Trident II or D-5) become more accurate (see page 38), the Soviets will view SLCM deployments as part of a larger U.S. attempt to attain a disarming counterforce capability. This will impel the Soviets to accelerate their efforts to acquire similar capabilities—resulting, in the long run, in decreased security for both sides.

**2. Limited nuclear war fighting weapon—**
Critics of the nuclear Tomahawk question the necessity of deploying the missile to fight a "tactical" nuclear war at sea. They argue that the U.S. does not need additional warheads to threaten targets of "naval interest," such as ports or airbases, and assert that it is far from certain that a tactical nuclear war could be kept limited for very long, since it would involve attacks on Soviet territory difficult to distinguish from "strategic" strikes, and would inevitably result in substantial damage to Soviet society. Deploying nuclear SLCMs in support of a warfighting strategy, critics hold, will only further contribute to the mistaken belief that a nuclear war can be controlled or won, when in actuality, any use of nuclear weapons is much more likely to result in a massive and mutually devastating exchange.

**3. Arms control: verification problems—**
Critics emphasize that the nuclear SLCM seriously threatens future prospects for verifiable arms-control agreements. Noting that the nuclear Tomahawk is externally indistinguishable from its conventional version, critics assert that the Tomahawk's presence cannot be detected easily through the usual "national technical means" of verification.

If national technical means are insufficient, say critics, any limits on nuclear SLCMs would have to rely on intrusive, on-site inspections (which may not be acceptable to either side and may not be fully effective) or on "counting rules" that would treat each SLCM carrier as a nuclear weapons platform. (Such rules have been used successfully to count air-launched cruise missiles, by assuming each platform holds up to a certain maximum load.)

Some opponents of the SLCM argue that although any SLCM negotiations will be complex, ultimately a total ban on nuclear SLCM deployment would be far easier to verify than would some numerical ceiling. Even if such a ban must provide for cooperative measures for verification (such as on-site inspections or the emplacement of "black boxes" to detect nuclear radiation or monitor SLCM production), arms-control advocates state that a ban, under which the deployment of even one new nuclear SLCM would be a violation, could be adequately verified.

Other arms-control advocates think a full-scale deployment ban may be difficult, but that strict limitations in U.S. and Soviet deployments are possible. Given that the U.S. has proceeded with the nuclear Tomahawk, and that Soviet deployments of new SLCMs are believed imminent, solutions other than a ban must be explored. For example, counting rules comparable to those developed to determine the numbers of warheads on ballistic missiles could be adapted for SLCMs. Such limits, despite a lack of precision, would be preferable to leaving SLCMs out of any future accord and thus creating a loophole the Soviets would surely exploit.

**4. Military utility—**
Some critics of the nuclear SLCM suspect the missile will never be able to perform its warfighting mission. They also doubt the desirability of transforming the entire U.S. fleet into a strategic target.

These critics point out that although the proliferation of nuclear weapons at sea may indeed complicate Soviet planning, such proliferation will greatly multiply the Soviet incentive to target the entire U.S. Navy for immediate destruction in any future conflict. This would accelerate Soviet anti-submarine and anti-ship warfare efforts, thereby reducing the survivability of our vessels.

**5. Response to Soviet capabilities—**
Does Soviet SLCM development justify U.S. development?—opponents of the nuclear Tomahawk point out that the Soviet threat is far from new: the Soviets have had nuclear-armed anti-ship SLCMs since the 1950s and nuclear land-attack SLCMs since the 1960s. Neither fact has concerned our strategic planners, mostly because the United States had (and has) a wide variety of nuclear systems for deterring the use of Soviet SLCMs.

Opponents concede that the new Soviet SLCMs are greatly improved, with increased range, accuracy, and speed; they assert, however, that the deployment of these weapons, far from providing a rationale for the nuclear Tomahawk, shows the need for arms control covering this type of weapon.

Opponents of the nuclear Tomahawk argue that the United States even with technologically superior SLCMs, would ultimately be the loser of an SLCM arms race because the United States, unlike the Soviet Union, has its major targets (capital, industrial centers, key military installations) near its coastline, within range of Soviet SLCMs. In this sense, opponents hold, the U.S.—and not the U.S.S.R.—is the most vulnerable to SLCMs, and should therefore lead the fight for a ban on deployment.

**6. Heightened nuclear tensions—**
Some opponents of nuclear SLCMs, who believe nonetheless in a strong and visible U.S. Navy, fear

that the potential for deployment of nuclear SLCMs on most major combatants will ultimately undercut the use of the U.S. Navy for "showing the flag" abroad, and could transform all naval shows of force into exercises in nuclear saber rattling.

These critics point out that there are many instances in which the United States wants to use the Navy to support diplomatic objectives, but in which a signal of nuclear capacity might be provocative. For example, if the battleship *New Jersey*, when deployed off Lebanon, had been armed with the nuclear SLCMs it is now slated to receive, its presence there might have been viewed as further escalating our involvement. It also might have become an attractive target to factional rivals in the region, who would have gained immediate recognition if they had attacked a strategic nuclear platform. By blurring the distinctions between nuclear and conventional naval power, critics fear, a Tomahawk-armed U.S. Navy could be handicapped in new ways.

**7. Complicates relations with allies—**
Critics note that nuclear SLCMs could complicate U.S.-Allied relations in some delicate negotiations relating to naval visits. Some of our allies prohibit the stationing of nuclear weapons in their territories. For example, New Zealand and Iceland ban all port visits of nuclear-armed U.S. warships. Even more of our allies have public constituencies that respond to visits of nuclear-capable vessels with large protests and anti-American demonstrations. Already a coalition of citizens' organizations in Japan has rallied against Tomahawk deployment, and Reagan Administration officials reportedly fear that Japan and other allies, such as Australia, Norway, and Spain, could take action to restrict U.S. naval visits—making future stops at "friendly" ports much more complex and contentious issues.

Recently, New Yorkers objected to the planned basing of the nuclear-weapons-capable battleship *Iowa* in New York. If such anti-nuclear concerns spread, even homeporting arrangements in the United States may be complicated.

### Verification Stance

The 1985 Defense Department Authorization Bill required the Administration to submit a report on SLCM verification. This report was submitted in classified form this April, and reportedly focuses on intrusive on-site inspection of U.S. and Soviet ships. Navy Secretary John F. Lehman has testified to Congress that the Navy will "accept whatever intrusive means of arms control inspection, including allowing Soviet inspection teams aboard our ships, whatever is negotiated."

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*A Tomahawk missile is launched from the U.S.S.* Merrill *(DD-976) in a 1983 test. (General Dynamics photo)*

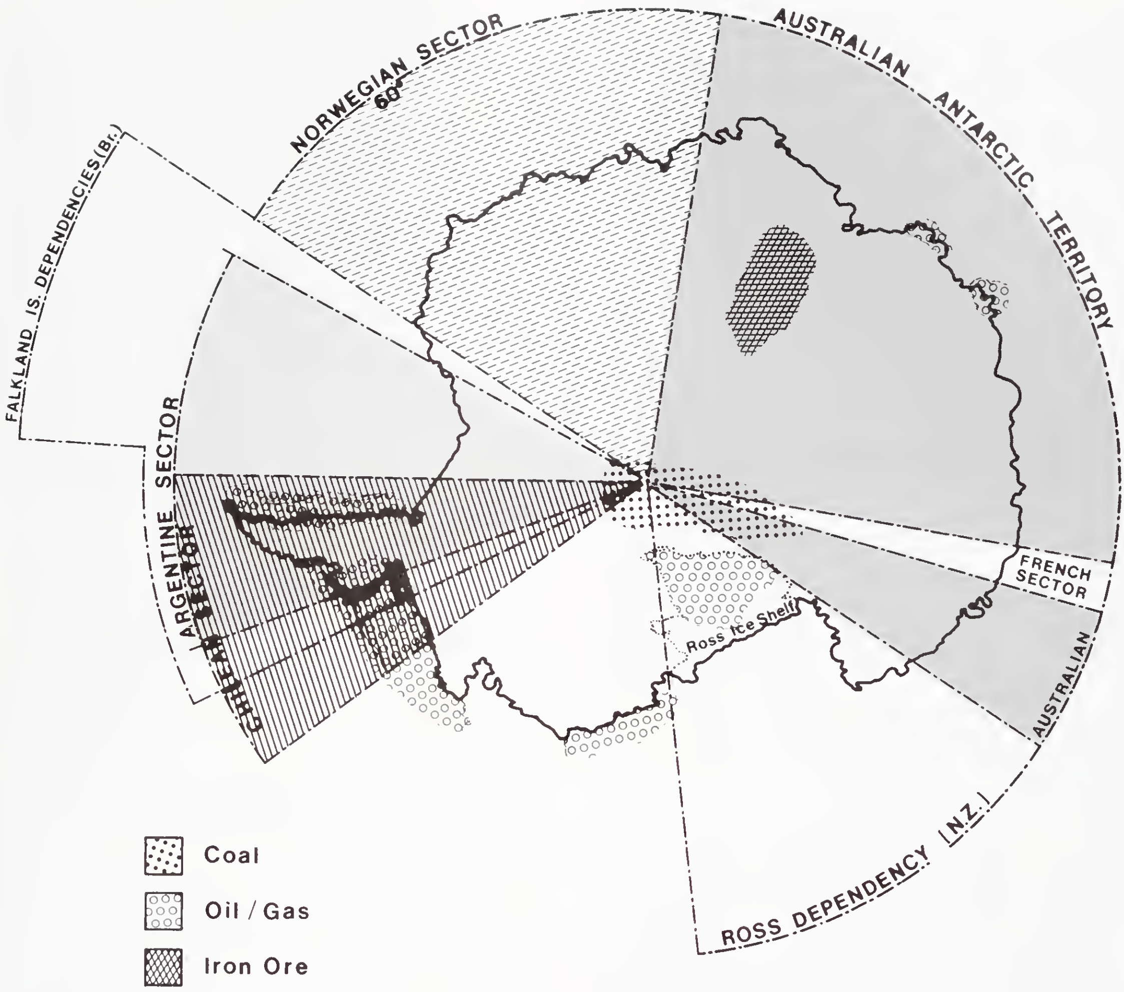

*North Atlantic Treaty Organization (NATO) and Soviet forces regularly deploy through the Arctic. Shown are potential NATO fleet movements (solid arrows), potential Soviet fleet movements (repeated arrows), and key zones for preventing a Soviet fleet breakout into the Atlantic or Pacific (hatched areas).*

# Polar Strategic Concerns

**by Melvin A. Conant**

In recent years, a great deal has been written about the untapped resources of the north and south polar regions in relation to our nation's strategic needs. Most of the writing has been speculation because there is inadequate geophysical coverage to date on these vast and inhospitable regions. Although comments such as "huge potential hydrocarbon deposits . . . more than 50 percent of the world's petroleum reserves lie north of the Arctic circle" are common, there is scant evidence to back them up. Regardless, enthusiasts of the polar regions persist in raising hopes of future "Eldorados." This may some day become true, but the prospects are so distant that our government or companies certainly cannot plan on it, even generally in their long-term strategic forecasts.*

* See Louis Ray's characterization in *Arctic Energy Resources*, Comite Arctique, September 1982.




*The Antarctic is claimed by a number of different nations; some of the claims overlap. Also shown are the locations of some potential resources, which are unlikely to be exploited in the near future.*

As for other resources, some see the world benefitting from storehouses of metals; some day, perhaps. But not until other sources in more accessible places have been depleted—a century possibly from now. Nowhere, however, in the Arctic or in the Antarctic, have commercially recoverable deposits of iron, copper, chrome, nickel, molybdenum, gold, silver, tin, and so on been found in large quantities, easily accessible.

Only in a very few areas of the north polar region have commercially recoverable petroleum reserves been established—on the North Slope of Alaska, and perhaps in the Canadian Beaufort Sea. Large fields may lie in the East Arctic Islands of the Canadian Archipelago, offshore of northern Norway, and in the Soviet Arctic (east and west), but they are not exploitable now, nor will they be in the foreseeable future. The Soviet Union, with urgent energy priorities, may use some other measure than "commercially recoverable" and hence will continue to explore and exploit their Arctic lands on a scale far surpassing the efforts of any other country.

This brings us to an aspect of the north polar region that is increasingly troublesome. What are the likely consequences of the ever-darkening Arctic haze—the result of pollutants from industrial economies—that has become so noticeable? Only a few decades ago the atmosphere in polar regions was clear. Could it be that concern about the Arctic's impact on weather worldwide will be of far greater importance than its prospective minerals or petroleum?*

* For a particularly useful review of non-defense North Polar matters, see *Arctic Ocean Issues in the 1980s and in the 1990s*, edited by Douglas M. Johnston, Law of the Sea Institute, University of Hawaii, 1981.

The strategic stakes in the polar regions, notably those in the Arctic, include the shadowy world of high-flying aircraft, missiles, and submarines. In the north polar region, many of the deadliest games of force and counterforce, of deterrence, and of matching weapon systems are in continuous play. It is an area of great importance to the defensive and offensive capabilities of both the Soviet Union and the United States.*

The south polar region does not have a strategic importance comparable to the North; the strategic value of the south lies chiefly where it did in World Wars I and II—in the ocean approaches to the Cape of Good Hope and to Cape Horn, and in the seas that stretch southward to the polar lands.

The importance of the Falklands in two world wars, and perhaps again in the recent confrontation between Britain and Argentina, is justification enough for a continuing British presence in that part of the world. But having mentioned these approaches to south polar seas, there is little to add about their strategic use.**

There may, however, still be occasions when national conflicts over jurisdictional claims will plague the Antarctic (for example, between Chile and Argentina (see page 93), or between Britain and Argentina), but these probably will be local engagements. Thus they would in no way be comparable to the more dangerous scenario of a massive clash of strategic forces in the north polar areas.

The north polar region is the shortest route the Soviet Union could take to the United States and Canada in the event of a war between the two superpowers. It thus would be the favored route for long-range strategic aircraft deployed out of the Soviet Far East, East Siberia, and from the complex of bases in the Soviet West Arctic, particularly on the Kola Peninsula, which houses the largest naval base complex in the world.

When manned aircraft were superseded by strategic missiles of intercontinental range it became possible to project trajectories in space streaming above the Arctic in both directions—aimed at North America and the industrial heartland of the Soviet Union. These missile systems have been succeeded but not displaced by another weapons system composed of nuclear-armed, low-flying intermediate range cruise missiles launched either from aircraft or from surface or submarine platforms. The advantage of the Arctic to most weapon systems is in the shortest alert time to the other side afforded by Arctic trajectories.

Hence, all countries involved in the use of Arctic spaces are committed to early warning systems that locate, identify, and analyze the purposes of aircraft and submarine movements. Sensors are placed along ocean bottoms, in the approaches to straits, or on land—as in the alert systems of North America, the North Atlantic Treaty Organization, and those of the Soviet Union. Other systems are airborne or in satellites that ceaselessly monitor every detectable movement in the waters, under the ice, and through space. These intricate networks are designed to alert defense forces to incoming weapons, to chart their paths, and to monitor and in some cases direct the ensuing battle. The next generation of sensors affecting the Arctic will almost surely be developed as part of what is now referred to as "Star Wars" or the U.S. Strategic Defense Initiative.

The forces maneuvering against each other in the Arctic have two critical and different tasks. From the viewpoint of the Soviet Union, it has to be able to send its naval forces out from the Kola base complex and from the Soviet Far East, past islands, straits, and other land configurations into the North Atlantic, or into the Arctic region and beyond. These Soviet naval units must be able to gather intelligence, maneuver, and search for U.S. naval ships. Unless Soviet naval forces, aided by aircraft and satellite detectors, can move through such constricted seas undetected, they cannot prevent NATO forces from moving into approaches to important Soviet bases on the Kola Peninsula, a protected haven for long-range missile systems, including nuclear submarines. Similarly, the Bering Strait is an important passage for the Soviet Union in moving ships to and from the Pacific.

For the forces of either side, the Arctic is thus a zone of transit or of hovering—and of waiting. Ice, which has been for centuries the bane of surface shipping, is a natural and secretive cover for submarines. Ice can be a screen between subsurface and atmospheric detectors; ice is also a continuously moving phenomenon whose location and effects on temperature gradients can conceal submarine movements, sometimes rendering these vessels undetectable to even the most sophisticated of antisubmarine warfare devices.

While the Soviet Union still has to deal with the same historic land and island barriers to the outward bound movement of ships, it does not have any need to make arrangements with allies to insure effective use is made of the Arctic or of the atmosphere above it. This freedom from political constraints is in marked contrast to NATO forces, which must rely on prior arrangements with Canada, Greenland, Iceland, Norway, Britain, and Japan. While most of the arrangements relate to seaborne forces and aircraft surveillance over the Greenland-Iceland-United Kingdom gaps, similar understandings pertain in the Pacific regarding Canadian and Japanese assistance to the United States.

Arctic detection networks across North

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* A most prescient interpretation of Arctic strategic stakes is found in G. R. Lindsey's *Stragetic Aspects of the Polar Regions*, Canadian Institute of International Affairs, Toronto, 1977.

** Far and away the most useful "briefing packet" on all aspects of the south polar region is provided by the International Institute for Environment and Development, 1717 Massachusetts Avenue, N.W., Washington, D.C. 20036. See *The Resource Guide on Antarctica* (including update, November 1, 1984).


*The U.S.S. Skate at the North Pole. (U.S. Navy photo)*

America range from Alaska to Greenland. These equire continuing technical improvements to insure heir effectiveness as weapon systems change and pproaches to tactics shift. There is now full cceptance in Canada of that nation's automatic (and navoidable) involvement both in countering threats o North America and in the support of U.S. strategic leterrent forces.

Most recently, Canada and the United States lecided that the Distant Early Warning Line, strung cross Canada, would be improved, at a cost of $1.2 illion (with Canada assuming for the first time a ignificant share of the expense—40 percent), into a ew North Warning System better able to cope with ew generations of weapons.

Canada and the United States also have edefined their plans for the defense of North America into an Air Defense Master Plan whose each is deep into the Arctic. None of these greements have been concluded easily, however. The Canadian reaction to U.S. testing of cruise nissiles over northern Canadian lands is a continuing eminder of that nation's reluctance to do more than t feels necessary in a common continental defense.

A major, if presently dormant, issue between Canada and the United States is the regime governing transit of ships through the Canadian Arctic Archipelago. Canadians assert these are "internal" waters or passages under Canadian erritorial control; the United States regards them as nternational passages. While much of this argument eflects Canada's assertion of its sovereignty, the ocus of the debate is on the practice of notification nd passage of warships—largely American—which neither country wishes to identify in ways helpful to he Soviet Union. This issue is unlikely to be resolved n the near future.*

There also are concerns in the United States about Greenlander and Icelandic attitudes toward their commitments to Atlantic defense. Their territories are so crucial to allied defenses that great pressure should be brought to bear to assure access to their lands. Any possibility, however remote, of a Soviet presence in these lands—including Svalbard—is unthinkable.

Svalbard is a possession of Norway. There is deep Soviet concern that these islands pose a threat to the Kola Peninsula. Moreover, because Svalbard lies on the southern edge of Arctic ice, Soviet naval passage between Svalbard and northern Norway is a near requirement—the waters consititute a naval "artery" for the U.S.S.R. Consequently, the Soviets would welcome neutrality for Svalbard; on the other hand, NATO has advantages in and near Svalbard that would be very difficult to relinquish in favor of "neutrality."* Moreover, Svalbard lies directly under the arc along which strategic missiles and long-range aircraft of either side presumably would fly.

The precise location of the Soviet-U.S. boundary as it lies through the Bering Strait and across the Navarin Basin (which may have an oil and gas potential) is an example of another strategic problem. This is a dispute that neither side is prepared to make an issue of at this time. Still, Navarin lies very close to a critical passage, important to the Soviet Union and to the United States.

On rare occasions, the United States tests Soviet reactions to U.S. ships approaching Soviet Arctic passages. Achievement of an all-weather capability would allow the Soviet Union the important strategic option of transferring some of its warships from the Barents to the Bering Sea, thereby avoiding the vulnerabilities of a long sea passage around the Eurasian continent.

For much of the last decade and a half, a

* For discussion of these matters, see *U.S. Arctic Interests in the 1980s and 1990s*, edited by Kurt M. Shusterich and William E. Westermeyer, Springler-Verleg, 1984.

* See "Defending the Far North," by Tomas Ries, in the *International Defense Review*, No. 7, 1984, and "Soviet Options on NATO's Northern Flank," Major General R. C. Bowman, USAF, Ret., in the *Armed Forces Journal*, April 1984.

common tactic used by both superpowers has allowed for long-range missile submarines to encroach on each other's territory. In recent years, this tactic has changed as the greatly increased range of submarine-launched ballistic missiles allows the vessels to remain close to home, obviating the earlier requirement to be in or transitting Arctic seas. In this respect, there is less need for strategic forces to exploit the Arctic environment. However, this has not closed down an Arctic watch by either superpower. If strategic surprise is ever achieved, it will most likely be by a complex mix of forces of which the long-range component may be the most important, but not the only element.

Finally, there is the goal of a number of Arctic peoples, including Scandinavians, to create nuclear-free zones in an effort to limit their own involvement in and exposure to nuclear tensions and perhaps to nuclear war itself. By having nuclear-free zones, the intention also is to set observable limits on where forces are and how they may operate. It is unlikely that proponents of such zones will succeed in establishing them, but those advocating them constitute a democratically organized voice in the Arctic. Whether their goal could, in fact, be achieved through the withdrawal of nuclear forces is less certain.

In short, it is regrettable, but unavoidable, that the northern polar region is so deeply enmeshed in the strategic maneuvering of the superpowers. But that is the condition; a circumstance which, for the foreseeable future, will overshadow resource development, concern over what is happening to global weather as a result of pollutants concentrated in the Arctic skies, or the appeals of peoples whose wish is to be left to their own desires and devices. If anything about the Arctic is certain, it is that it will be decades before the strategic imperatives mentioned in this article will fade away; would that it could be otherwise.

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## Letter Writers

The editor welcomes letters that comment on articles in this issue or that discuss other matters of importance to the marine community.

Early responses to articles have the best chance of being published. Please be concise and have your letter double-spaced for easier reading and editing.


*Like the Coast Guard itself, this 378-foot high endurance cutter (the U.S.C.G.C. Sherman) must tackle numerous missions, including long-range search and rescue, ocean station patrol, and military readiness. She is based in Boston, Mass. (U.S. Coast Guard photo)*

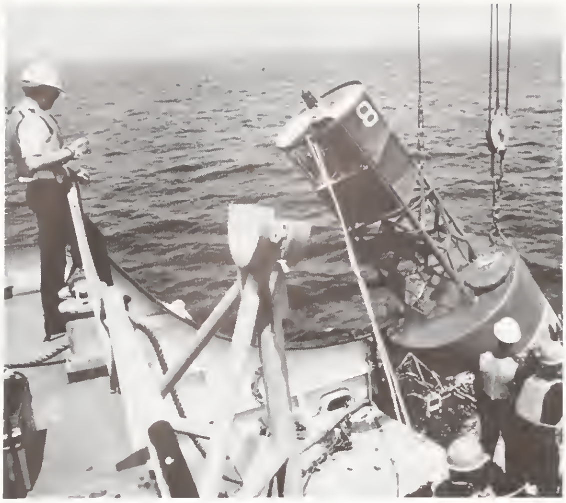
# The Role of the U.S. Coast Guard

## by Porter Hoagland III

Throughout its history, the missions of the United States Coast Guard have paralleled ocean-use patterns in the United States. Today, the Coast Guard has regulatory or enforcement authority for drug smuggling, illegal immigration, a coastal military "maritime defense zone," piracy, search and rescue of lives in peril at sea, buoys and lighthouses, vessel traffic, port security, fisheries management, ocean dumping, oil pollution, and marine sanctuaries, among others (see Table 1). These multiple and sometimes disparate responsibilities are tied together by the Coast Guard's ability to operate in the marine environment. Because the Coast Guard's responsibilities enhance the welfare and safety of U.S. citizens in their use of ocean resources, the

Table 1. U.S. Coast Guard missions.

| Mission | Responsibility |
|---|---|
| Enforcement of Laws and Treaties | Cutter and aircraft patrols on the high seas and within U.S. jurisdiction for: drug smuggling, illegal immigration, highjacking or theft of vessels, fisheries violations, other unlawful activities. |
| Search and Rescue | Nationwide system of boats, aircraft, cutters, and rescue coordination centers on 24-hour alert. |
| Aids to Navigation | Short-range aids to navigation (buoys and lights), long-range aids to navigation (Loran-C), bridge administration, and domestic icebreaking. |
| Marine Safety | Merchant vessel inspection, licensing of merchant-marine personnel, boat safety standards, recreational boater education, Coast Guard Auxiliary support, and ports and waterways security. |
| Marine Environmental Protection | Aerial oil pollution patrols, pollution investigations, monitoring cargo transfer operations, oil pollution removal, hazardous substance spill cleanup, ocean dumping surveillance. |
| Military Readiness | Individual and unit training, joint naval training exercises, and Coast Guard single and multiship operations in: antisubmarine warfare, inshore undersea warfare, convoy escort, and selected other responsibilities. |
| Polar Ice Operations | Icebreakers or ice-strengthened cutters operate to facilitate commerce, support Coast Guard programs, and support the requirements of other federal agencies on a reimbursable basis. |



*Buoy tending (maintaining navigational buoys) is one of the Coast Guard's responsibilities. (U.S. Coast Guard photo)*

Coast Guard contributes in a very real sense to the security of the nation.

**History**

The Coast Guard's law-enforcement mission predates its other missions. In 1789, Congress established customs duties on all imports as well as tonnage duties on maritime shipping. This was a first step toward financing the nascent republic's burgeoning national debt. The following year, Congress created the Revenue Cutter Service as an agency of the Treasury Department to enforce customs laws. When the U.S. Navy became a permanent, cabinet-level department in 1798, Congress established that, in the event of a national emergency, the Revenue Cutter Service could be transferred from the Treasury to the Navy Department.

The Revenue Cutter Service's maritime duties grew over the years as the value of an ocean-going constabulary became more apparent. Early on, the service conducted search-and-rescue operations as a sideline to customs enforcement. In 1819, the service was given authority to suppress the slave trade and piracy. Later, such diverse tasks as provision of medical aid to deep-sea fishermen, suppression of merchant vessel mutinies, protection of the safety of lives at sea during regattas and marine parades, and enforcement of sponge-fishing regulations were added to its responsibilities.

Congress authorized the Lifesaving Service—established in 1848 along U.S. coasts to aid in the rescue of lives and property from shipwrecks—to merge with the Revenue Cutter Service in 1915. This combination became known as the Coast Guard. The Coast Guard increased its responsibilities by assimilating other agencies, including, in 1939, the Lighthouse Service and, in 1942, the Bureau of Marine Inspection and Navigation. Several unsuccessful attempts have been made to move the Coast Guard from the Treasury Department: first to the Navy after World War I, then to the Commerce Department in the late 1960s (into a proposed National Oceanic and Atmospheric Administration), and more recently to the Defense Department.

In 1967, in part because of its increasingly diverse responsibilities concerning marine transportation, the Coast Guard was moved from Treasury to the newly formed Department of Transportation (DOT). Within DOT, the Coast Guard is both a maritime regulatory agency and a law enforcement arm of the federal government. Additionally, the Coast Guard remains one of the five armed services of the United States.

During World Wars I and II, the Coast Guard was transferred temporarily to the Navy Department. Since then, although no international conflict has been of a scale to require such a transfer, smaller numbers of Coast Guard ships and personnel have been placed under the direction of the Navy. The Coast Guard served in Korea, where it organized a South Korean Coast Guard; in Vietnam, where it worked as a coastal and riverine naval force; and in Grenada, where it provided a post-invasion security presence.

In very recent history (the 1970s), Congress has enacted laws that give the Coast Guard substantial new responsibilities, particularly in the areas of water pollution control, ports and waterways safety, and fisheries enforcement. Coast Guard resources, however, have increased at a decidedly slow pace, incommensurate with this recent growth of responsibility.

**Resources**

About the size of the Department of Justice, the Coast Guard has more personnel and a larger budget than the Department of Commerce. On the other hand, Coast Guard resources (personnel, budget, and physical capital) are small in comparison with those of the other U.S. armed forces. The Coast Guard maintains about one-twentieth of the U.S. Navy's manpower.

The Coast Guard employs roughly 39,000 active-duty military personnel; 5,500 civilians; and 12,250 selected reservists, who are ready to be activated in an emergency. It also has a unique volunteer civilian component called the Coast Guard Auxiliary, which numbers approximately 40,000. The Auxiliary assists the Coast Guard in search and rescue, boating safety, and public education.

From 1981 to 1984, the number of Coast Guard personnel, both military and civilian, has remained relatively stable. In the late 1970s reenlistment was a substantial problem, dropping to a low of 16 percent in 1979. However, recent pay hikes for military personnel and the lack of employment opportunities outside the service have boosted the reenlistment rate after a first term of service (usually four years) to almost 60 percent. It is unclear what the effect might be on this service of the recent discussions of cuts in military retirement benefits.

The Coast Guard's operating budget represents almost two-thirds of its total annual budget (approximately \$2.5 billion—see Figure 1).

The other third includes capital expenses and a general category that covers retirement pay and reserve training, among other things. During the late 1970s and early 1980s, the Coast Guard's total budget actually declined in real (adjusted for inflation) dollars, even as regulatory responsibilities grew.

Enforcement of laws and treaties, search and rescue, and aids to navigation remain the Coast Guard's most important missions, accounting for almost two-thirds of the operating budget. During the three-year period, 1981 to 1984, the Coast Guard's budget increased about 5 percent in real terms. Law and treaty enforcement, military readiness, and marine environmental protection gained in funding, while the budget shares of polar icebreaking operations and marine safety missions were cut back. The Coast Guard's operating expenses for enforcement of laws and treaties now exceed those for search and rescue.

One physical capital resource limitation for the service has always been its aircraft and cutters (vessels more than 65 feet long). The Coast Guard has 49 high- and medium-endurance cutters (Table 2). A high-endurance cutter is expected to be able to operate at sea for an extended period of 30 to 45 days, while a medium-endurance cutter can operate at sea for 10 to 30 days. Several of these cutters have been in service more than 40 years, which makes them quite old. Downtime—when a cutter is not in use because of routine maintenance oı a breakdown—has been a problem; in 1984, all cutters together averaged 36.7 percent downtime (see Figure 2). By the late 1980s, the Coast Guard will be decommissioning old cutters at a faster rate than it will be bringing new cutters on line.

Because of this age factor, the Coast Guard is in the midst of an ambitious building and renovation program for both cutters and smaller utility boats. The agency is working on the design of several new, small boats, as well as a 600-ton catamaran or SWATH (small waterplane area twin-hull) vessel. The 378-foot *Hamilton*-class cutters, 210-foot *Reliance*-class cutters, and 180-foot buoytenders are undergoing a mid-life extension program, including powerplant overhauls, mechanical refurbishing, and ordnance modernization. Four new 270-foot *Bear*-class medium-endurance cutters have been delivered, and nine more are expected by the early 1990s. In this decade, although absolute numbers of cutter-days available may be a limitation, the condition of the cutter fleet should improve.

The Coast Guard has about 98 helicopters and 54 fixed-wing aircraft at 26 air stations around the United States. The Coast Guard will replace many of its old helicopters with 90 new *Dolphin* twin-turbine short-range helicopters. These new helicopters are built primarily for emergency search-and-rescue activities but also may be used for pollution patrol, aids to navigation, and law enforcement. The workhorses of Coast Guard aircraft are its 19 C-130 *Hercules* long-range cargo-

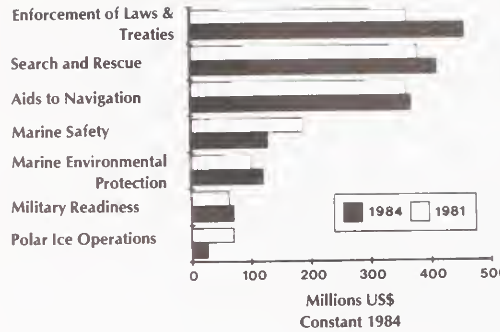



*Figure 1. The Coast Guard's operating budget for 1984 was almost $1.6 billion, and was divided between a number of different missions.*

**Table 2. U.S. Coast Guard high- and medium-endurance cutter service life summary**[a] (As of April 1, 1984)

| Number | Class | Average Age (years) |
|---|---|---|
| ***High Endurance Cutters*** | | |
| 12 | 378′ *Hamilton* | 15 |
| 4 | 327′ *Secretary* | 48 |
| 1 | 311′ *Unimak* | 42 |
| ***Medium Endurance Cutters***[b] | | |
| 1 | 230′ *Storis*[c] | 42 |
| 3 | 213′ *Acushnet*[c] | 41 |
| 16 | 210′ *Reliance* | 17 |
| 5 | 205′ *Cherokee* | 42 |
| 3 | 180′ *Balsam* | 42 |
| ***Total*** | | |
| 45 | | 26 |

[a] Coast Guard cutters have a designed service life of 30 years.
[b] Four new 270′ *Famous* class (also known as the *Bear* class) cutters are not included in this summary.
[c] These cutters are undergoing renovations that will add about 11 years to their working lives.

Source: U.S. Coast Guard, 1985.

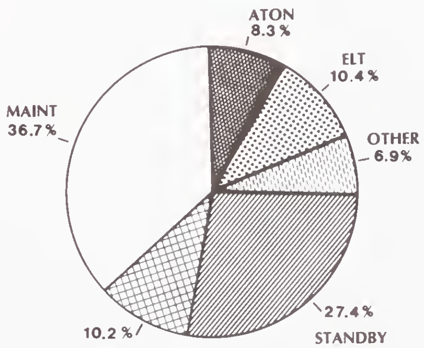



*Figure 2. Total hours for Coast Guard cutters in 1984 (total hours are defined as the number of hours that cutters are in high readiness—the ability to be underway in less than six hours). The categories of missions are: Aids to Navigation (ATON), Enforcement of Laws and Treaties (ELT), Search and Rescue (SAR), and all other missions. "Standby" means the cutters are not being used because of personnel constraints. "Maintenance" means cutters are not being used because they are undergoing necessary, routine maintenance or repairs of breakdowns. Source: U.S. Coast Guard, 1985.*

*The Coast Guard icebreaker* Polar Star *breaks a swath through ice in McMurdo Sound off Antarctica. (U.S. Coast Guard photo)*

transport turboprops. Several of the C-130s will require major renovations or replacement soon. The Coast Guard recently acquired 41 *Falcon* search-and-surveillance fixed-wing jets. Some *Falcons* will be equipped with the highly sophisticated AIREYE infrared surveillance system. AIREYE can detect, map, and identify selected targets such as oil spills. The effective use of this aircraft has been slowed by technical problems with its engine.

**Mission Priorities**

In 1982, Vice President George Bush headed a task force aimed at two apparent problems in the southeastern United States: the increased immigration of people from Caribbean countries (such as Cuba and Haiti), and the smuggling of drugs. The Vice President charged the Coast Guard to "immediately and significantly increase its forces and manpower in the south Florida area to help in the coming months with the interdiction of illegal drugs and aliens." Subsequently, Admiral John B. Hayes, the Commandant of the Coast Guard, testified before Congress that this shift in priorities would necessitate reductions in north and central Atlantic search-and-rescue response capabilities and fisheries enforcement patrols.

This case illustrates the Coast Guard's renowned mission-switching, or multimission, capability. Mission-switching allows the Coast Guard to quickly readjust priorities. Thus it can enforce fisheries regulations with its buoytenders and interdict drug smugglers with its search-and-rescue helicopters. In fact, many Coast Guard seamen are cross-trained as policemen, linguists, biologists, accountants, and soldiers. This has paid off in situations such as the Vietnam conflict, where the Coast Guard used its expertise in shallow-water boat handling and contraband control to thwart coastal arms smuggling by the North Vietnamese.

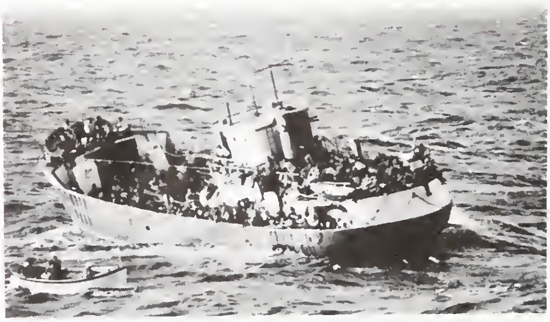
The Coast Guard's national security role is shaped by the seemingly unlimited number of ocean uses. The Coast Guard's resources, however, are limited. To a degree, the Coast Guard can accommodate increasing demands for its services through more effective use of its internal resources. For example, in 1984, Coast Guard cutters "stood by" an average of 27 percent of the time (see Figure 2). Standby time results primarily from personnel constraints such as time needed for a crew's education, liberty, and leave. The Coast Guard has been evaluating various means, such as pay incentives (more pay for hazardous or undesirable duties, for example), to reduce standby time. A cutter that is at sea or in a high-readiness posture for a larger portion of its total hours may be more effective in responding to the demands of the various Coast Guard responsibilities.

Not surprisingly, certain missions sometimes receive a higher priority than others. A wartime emergency is a clear example. On a short-term basis, mission-switching is a way for the Coast Guard to set priorities among missions and to distribute its resources more effectively. As ocean uses in the United States grow in importance, however, decisions will have to be made to direct the Coast Guard's limited resources toward those uses with the greatest long-term potential for enhancing the welfare and safety of U.S. citizens.

**Inter-agency Coordination**

Just as the Coast Guard economizes through better use of its internal resources, inter-agency relationships can provide access for the Coast Guard to external resources needed for accomplishing its own missions. For example, in the southeastern United States, Navy ships on routine maneuvers have been used as platforms for Coast Guard boarding officers conducting drug interdiction. Moreover, between 1984 and 1989, the Navy plans to contribute more than $400 million of its own funds to install and upgrade ordnance and defense-related electronic equipment aboard Coast Guard cutters and aircraft.

In the conduct of its national security missions, the Coast Guard coordinates extensively with other federal agencies. The Coast Guard works with, among others, the Federal Bureau of Investigation in counteracting domestic terrorist



*A U.S. Coast Guard launch approaches a ship of Haitian refugees. (U.S. Coast Guard photo)*

activities; the Drug Enforcement Agency in drug interdiction efforts; the National Marine Fisheries Service in fisheries enforcement; and the Environmental Protection Agency in oil and hazardous substance control.

The Coast Guard and the U.S. Navy have established a joint policy group (similar to one between the Navy and the Marine Corps) known as the NAVGUARD Board. The NAVGUARD Board comprises seven Coast Guard and seven Navy flag officers (admirals) and is chaired jointly by the Vice Commandant of the Coast Guard and the Vice Chief of Naval Operations. The primary role of the NAVGUARD Board has been to promote coordination between the two services for national defense purposes.

In the event of war, the Coast Guard will further increase its coordination with the Navy, as well as take on additional responsibilities. As a result of a 1982 NAVGUARD Board study, the Coast Guard Commanders in the Atlantic and Pacific became responsible for planning and conducting U.S. defense activities in a coastal "maritime defense zone." The Coast Guard is now undertaking contingency plans to prepare for coastal and harbor defense, thus adding to its peacetime responsibilities as well. The NAVGUARD Board suggested several other areas in which the Coast Guard could add to or expand its wartime responsibilities (see Table 3). While it is to be expected that Coast Guard resources would be increased during such an emergency, certain mission responsibilities would nonetheless receive a lower priority—most likely bridge administration, recreational boating safety, certain marine environmental protection activities, and certain law enforcement activities.

**Table 3. General transfer of Coast Guard responsibilities from peacetime to wartime**

| Mission | Peacetime | Wartime |
|---|---|---|
| Enforcement of Laws and Treaties: | | |
| Coastal surveillance and interdiction | X | X[a] |
| Other responsibilities | X | — |
| Search and Rescue: | | |
| Wartime search and rescue | — | X[a,b] |
| Wartime salvage | — | X[a] |
| Other responsibilities | X | X |
| Aids to Navigation: | | |
| Short range aids | X | X |
| Radio navigation | X | X |
| Bridge administration | X | — |
| Domestic Icebreaking | X | X |
| Marine Safety: | | |
| Port safety and security | X | X[a] |
| Merchant vessel safety | X | X |
| Recreational boating safety | X | — |
| Marine Environmental Protection: | | |
| Flammable chemical response | X | X |
| Hazardous chemical response | X | X |
| Other responsibilities | X | — |
| Polar Ice Operations | X | X |
| Military Readiness: | | |
| Antisubmarine warfare | X | X[a] |
| Inshore undersea warfare | X | X[a] |
| Wartime Tasking: | | |
| Naval control of shipping | — | X[b] |
| Harbor defense and security | — | X[b] |
| Mine countermeasures | — | X[b] |

[a] Responsibilities that are expanded during wartime.
[b] Responsibilities that are added during wartime.
Source: NAVGUARD Board, 1981, as reported by the House Merchant Marine and Fisheries Committee.

## User Fees

The pressure of increasing responsibility has forced the Coast Guard to re-evaluate its mission priorities, to increase the size of its resource base, to seek assistance from other agencies, and to examine means of support other than the federal budget. Within the last few years, several studies have been published that discuss Coast Guard responsibilities and priorities (see Additional Readings). The concept of user fees was recommended in each of these studies. A user fee is a charge imposed by a government agency on an individual or group of individuals (rather than on the public in general) to cover the cost of a particular service.

Considerable dispute exists over the user fee concept, and thus far it has not been employed by the Coast Guard. At a general level, those organizations that have studied the Coast Guard are not in complete agreement over which services should be subject to user fee charges (see Table 4). User fees could provide extra funding for some Coast Guard services, but then federal budget support for those services probably would be cut back, resulting in a negligible net increase. Some other potential problems revolve around the effects of the charges on user behavior. Would ocean users in danger be reluctant to call for Coast Guard assistance, knowing that they must pay for it, and thus put themselves and others in greater peril? Would ocean users expect more from the Coast Guard, such as professional medical care from

**Table 4. General comparison of recommendations for Coast Guard user fees by mission.**

| Mission | 1981 HOUSE | 1982 SENATE | 1982 DOT | 1983 NACOA | 1985 H.R. 1936 |
|---|---|---|---|---|---|
| Enforcement of Laws and Treaties | | | (No User Fees Recommended) | | |
| Search and Rescue | | | X | X | X |
| Aids to Navigation | | | X | X | X |
| Marine Safety | | | X | | X |
| Marine Environmental Protection | | X | | | X |
| Military Readiness | | | (No User Fees Recommended) | | |
| Polar Icebreaking Operations | X | | X | | |

Sources: After NACOA, 1983.

*U.S. Coast Guard personnel direct ship traffic through Puget Sound. (Photo by Lowell Georgia, Photo Researchers)*

search-and-rescue personnel, for services that are paid for directly?

In April of this year, a bill (H.R. 1936) was introduced in the House of Representatives by Silvio Conte (R-Mass.), a ranking member of the Appropriations Committee, that would establish user fees for the operating expenses of certain Coast Guard services. The bill explicitly mentions several responsibilities within the marine safety mission, and includes implicitly all responsibilities except those that fall under enforcement of laws and treaties, polar ice operations, military readiness, and certain waterways management programs.

Perhaps the most controversial category of user fees implicit in H.R. 1936 is that they might be charged for the search-and-rescue mission. The bill would result in the identification of people who are saved or otherwise assisted at sea (190,000 in 1980) as a special user group. Especially in peacetime, the search and rescue of recreational boaters and commercial vessels may contribute as much toward enhancing the welfare and safety of U.S. citizens as military readiness responsibilities. In 1980, for each U.S. citizen the federal government spent about half a cent on Coast Guard search and rescue. (By comparison, that same year about $630 went to the U.S. military budget for each citizen.) In 1980, more than $1 billion in property loss was prevented through Coast Guard search and rescue operations. This figure is approximately equal to the Coast Guard's operating budget for *all* of its missions in that same year.

In the broad definition of national security embodied by the Coast Guard, the concept of user fees presents an enigma. Inherent in the user-fee concept is the premise that a particular Coast Guard responsibility contributes more to the security of a particular group than to the nation as a whole. Thus the group is charged for the costs of providing that security. In House bill H.R. 1936, marine safety activities such as search and rescue or merchant vessel inspections are considered contributory to the security of particular groups. Activities that concern law enforcement or defense are considered contributory to the national security. Any congressional deliberation of this bill will involve a philosophical debate over the degree to which government should be involved in enhancing the welfare and safety of individual U.S. citizens who use the resources of the ocean. In the future, the national security role of the Coast Guard may be redefined with respect to those responsibilities that involve user fee charges.

**Conclusion**

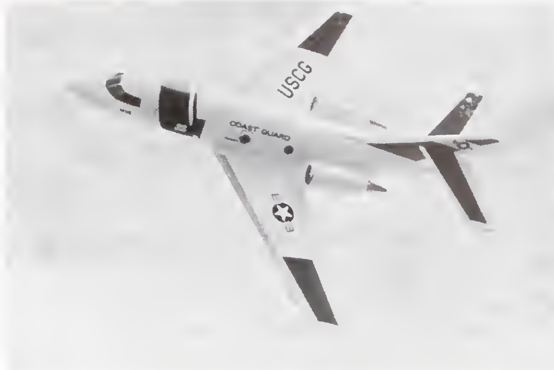
The Coast Guard's current Commandant, Admiral James S. Gracey, recently explained to the U.S. Reserve Forces Policy Board that "National security is indeed what the Coast Guard is all about—but in many ways we differ from our partners in the Department of Defense." Indeed, understanding the role of the Coast Guard in the oceans and national security requires a broad definition of national security— one that includes those responsibilities that enhance the welfare and safety of U.S. citizens.

Virtually all of the Coast Guard's mission responsibilities fall within that broad definition. But as the uses of the oceans become more diverse, Coast Guard responsibilities grow apace. The Coast Guard faces these increasing responsibilities with limited resources. Any understanding of the Coast Guard's national security role is incomplete without a knowledge of how the agency handles this


*A U.S. coastguardsman records data on a Soviet ship. (U.S. Coast Guard photo)*

problem. In unique fashion, the Coast Guard has been able to accommodate many new responsibilities through the re-setting of long-term priorities and mission-switching in the short-term. Coordination with other agencies and selective resource increases also have helped the Coast Guard handle increasing demands. Other means of support for Coast Guard services, such as user fees, may be employed in the future.

The missions and responsibilities of the Coast Guard recently have received a great deal of attention. The agency deserves this attention: it is a national asset that contributes substantially to the national security of the United States.



*Falcon jets like the one shown above are to be used by the Coast Guard for detection of marine pollution, search and rescue, and other tasks. Use of the aircraft has been held up by engine problems. (U.S. Coast Guard photo)*

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**Acknowledgment**

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# Soviet Naval Forces

**EDITOR'S NOTE: The following material has been excerpted and edited from *Soviet Military Power 1985,* a publication of the U.S. Department of Defense. This material also draws on force comparison studies conducted in 1984 by the North Atlantic Treaty Organization (NATO). The purpose of the piece is to give the reader a sense of how the United States perceives Soviet naval capabilities.**

The growth of the Soviet Navy since 1960 and the expansion of its oceanic areas of operation have made it a highly visible symbol of increasing Soviet military capabilities. During this period, the ballistic missile submarine force has become an important strategic arm of the Soviet Armed Forces.

The Soviets maintain the world's largest ballistic missile submarine force. As of early 1985, the force numbered 62 modern nuclear ballistic missile submarines (SSBNs) carrying 928 nuclear-armed missiles. These totals do not include 13 older submarines with 39 missiles. Eighteen SSBNs are fitted with 300 Multiple Independently-targetable Re-entry Vehicle (MIRV) equipped submarine-launched ballistic missiles (SLBMs). These 18 units have been built and deployed within the last 8 years. More than two-thirds of the ballistic missile submarines, including those equipped with MIRVed missiles are fitted with long-range SLBMs that enable the submarines to patrol in waters close to the Soviet Union. This affords protection from NATO antisubmarine warfare operations. Moreover, the long-range missiles allow the Soviets to fire from home ports, if necessary, and still strike targets in the United States.

Three units of one of the most modern Soviet ballistic missile submarine, the Typhoon, have already been built. Each Typhoon carries 20 SS-N-20 solid-propellant MIRVed SLBMs. The Typhoon is the world's largest submarine, with a displacement of 25,000 tons, a third greater than the U.S. Ohio-Class (Trident). The submarine can operate under the Arctic Ocean icecap, adding further to the protection afforded by the 8,300-kilometer range of the SS-N-20 SLBM. Three or four additional Typhoons are probably now under construction, and, by the early 1990s, the Soviets could have as many as eight of these weapon systems in operation. The Soviet Navy's power, mobility, and capability for worldwide deployment give it the ability to support state interests abroad to a degree unmatched by other branches of the military. Because the Soviet Navy has evolved from its own particular national political requirements and geographic constraints, its missions, organization, structure, and composition differ appreciably from those of the U.S. Navy.

While the modern Soviet Navy has not been tested in battle, it is clearly designed and structured for wartime tasks. Overall, the missions of the Soviet Navy are to conduct strategic strikes against land targets, to provide for the maritime security of the U.S.S.R., and to support Soviet policy and promote Soviet interests worldwide.

### Naval Organization

The Soviet Navy is headed by a Commander in Chief (CINC) who is also a Deputy Minister of Defense; he functions as the equivalent of both the U.S. Secretary of the Navy and the Chief of Naval Operations and is the chief adviser on naval policy to the Minister of Defense. Fleet Admiral of the Soviet Union Sergei G. Gorshkov has commanded the Navy since 1955, and was appointed Deputy Minister of Defense in 1956. He is assisted by several deputies who supervise the day-to-day operations of the Navy, including the work of more than 10 staff directorates.

The Soviet Navy is comprised of four major fleets: Northern Fleet, Pacific Ocean Fleet, Baltic Fleet, and Black Sea Fleet. Fleet headquarters are located at Severomorsk for the Northern Fleet, Vladivostok for the Pacific Ocean Fleet, Kaliningrad for the Baltic Fleet, and Sevastopol for the Black Sea Fleet. Under each fleet commander there are several major operational elements, including surface and submarine forces, naval base commands, naval aviation, and naval infantry. While the fleet commands provide administative, logistic, and operational support to the strategic submarine force, operational control of Soviet SSBNs is at the national level.

### Submarines

A significant part of Soviet naval strength lies in its general purpose submarine force, the largest in the world. Today, this force numbers some 300 active units composed of some 25 different classes of torpedo attack, cruise missile, and auxiliary submarines. Nearly half the force is nuclear powered, and this percentage is expected to rise in the years ahead.

Currently, the Soviets are producing or testing nine different classes of submarines. Of these, all but one are nuclear powered. This program spans the entire range of undersea warfare applications including torpedo and anti-ship cruise missile attack, land-attack sea launched cruise missiles (SLCM), technology research, and specialized communications support. The newest Soviet submarine designs show evidence of an emphasis on quieting, speed, nuclear propulsion, weapon versatility, and incorporation of advanced technologies.

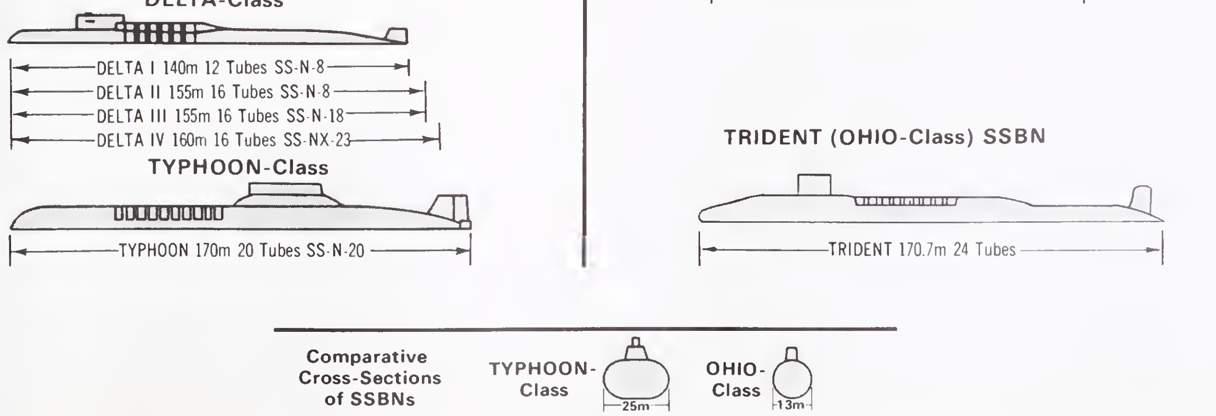
Since 1983, four new classes of nuclear-powered attack submarines have been introduced. The Mike SSN, at almost 10,000 tons, embodies the Soviets' state-of-the-art in propulsion and pressure

*The reach of Soviet naval forces, including strategic missile submarine operating areas, overseas port and airfield access, and fleet operational areas.* (*After* Soviet Military Power 1985)

hull design. It is capable of firing a wide range of submarine-launched weapons, including the SS-N-15 nuclear depth bomb, the SS-N-16 antisubmarine warfare (ASW) missile, and possibly the SS-NX-21 land-attack SLCM.

The second nuclear-powered attack submarine introduced in 1983 was the Sierra. At 8,000 tons, the Sierra is about 20 percent larger than the Victor III, which was introduced only four years earlier. In this era of rapidly developing technologies, the Sierra is a clear demonstration of the high priority that submarine development programs receive in the Soviet Union.

A third submarine development of 1983 typifies another aspect of Soviet philosophy, which is to incorporate new innovations into older designs,



thus extending the service life and tactical utility of its submarine force. In this case, the ballistic missile tubes were removed from a Yankee SSBN in a process that converted the unit to an attack submarine. This Yankee SSN has probably been re-equipped with updated systems, such as fire control and sonar, in addition to other modifications that will enable it to launch a wider variety of weapons.

In 1984, another new class of nuclear-powered attack submarine—the Akula-Class—was launched. The lead Akula unit is also similar to the Victor III- and Sierra-Classes.

**Surface Forces**

The surface forces of the Soviet Navy conduct a broad range of naval operations, especially in waters distant from the U.S.S.R. In general, the afloat forces are modern and well equipped.

The trend in Soviet major surface warship programs has been toward larger, technologically more sophisticated units. Construction of these Soviet ships over the last decade has produced increasingly larger ships with an upgraded array of weapon systems and complementary sensors. These ships can cruise for longer distances, carry more ordnance, and conduct a greater range of operations than their predecessors. This has created a new flexibility and versatility for Soviet surface forces in carrying out deployed operations on a worldwide scale.

Currently, the largest ship in the Soviet Navy is the Kiev-class aircraft carrier. Its weapons suite includes a battery of 550-kilometer-range SS-N-12 antiship cruise missiles that can be targeted beyond the ship's horizon by onboard Hormone helicopters or information derived from satellites or land-based long-range aircraft. This class also carries an array of other weaponry and support equipment, including more than 100 long- and short-range surface-to-air missiles, air defense gun batteries, tactical sensors, electronic warfare systems, and advanced communications devices. The 600-foot flight deck accommodates both Hormone and Helix helicopters and Forger vertical/short take-off and landing (V/STOL) aircraft that are capable of daylight attack, reconnaissance, and intercept missions.

A new era in Soviet warship development began in 1980 with the appearance of the initial units of the most technologically advanced classes yet produced. These included the first Soviet nuclear-powered surface warship—the *Kirov* guided-missile cruiser—and the *Udaloy* and *Sovremennyy* guided-missile destroyers. In 1982, the first of a new class of gas-turbine-powered guided-missile cruisers—the *Slava*—entered the inventory. The *Slava* is equipped with 16 SS-N-12, 550-kilometer range antiship cruise missiles, 64 SA-N-6 air defense missiles, 40 SA-N-4 point defense missiles, a 130-mm twin-barrel, dual-purpose gun, and the surveillance variant of the Hormone helicopter.

Each of these classes is currently in series production and illustrates the Soviet Navy's trend toward construction of larger displacement ships with greater firepower, endurance, and sustainability for distant operations. The *Kirov* CGN, with a displacement of about 28,000 tons, is the largest warship, with the exception of aircraft carriers, built by any nation since World War II. Its principal armament is a battery of 20 550-kilometer SS-N-19 antiship cruise missiles, complemented by launchers for the SS-N-14 antisubmarine missile in the first ship of the class only. Three Helix or Hormone helicopters are carried onboard for ASW and missile targeting.

Other new construction combatant programs show similar evidence of Soviet concern for the multidimensional aspect of modern naval warfare. All new principal surface combatants are equipped with surface-to-air missiles and sensors and weapons for antisubmarine warfare, in addition to helicopters and specialized weaponry. The *Sovremennyy* DDG, for example, is estimated to carry 44 SA-N-7 short-range surface-to-air missiles, a Helix helicopter, 53cm torpedoes, and 120 antisubmarine rockets, as well as 8 SS-N-22 supersonic antiship missiles.

A newer era still in Soviet naval development will begin soon with the launching of a new type of aircraft carrier now under construction at Nikolayev in the Black Sea. Expected to displace some 65,000 tons, this new unit will probably incorporate a nuclear propulsion system based on that of the *Kirov* nuclear-powered guided-missile cruiser CGN.

The ultimate flight deck configuration of the new carrier is still not confirmed, and the aircraft for its air wing are still under development.

**Naval Aviation**

Although there will be an increasing emphasis on sea-based aircraft development, Soviet Naval Aviation (SNA) will remain primarily a land-based force. Numbering more than 1,600 aircraft, SNA alone is larger than most of the national air forces in the world today. Since the mid-1950s, when the force was first equipped with missile-carrying jet bombers, weapon systems and tactics associated with its principal antiship strike mission have been progressively upgraded. The Tupelov-designed variable-geometry-wing Backfire bomber entered the SNA inventory in 1974 and is currently deployed in the Black Sea, Baltic Sea, and Pacific Ocean Fleets. The Backfire can carry antiship missiles, bombs, or mines and exhibits marked improvements in performance, nearly doubling the combat radius of its Badger and Blinder predecessors.

Swing-wing fighter-bombers are also assigned to SNA. Its Fitter C aircraft, which can carry more than 7,000 pounds of ordnance, are well suited to such roles as the support of Soviet amphibious forces and antiship attacks against fast and highly maneuverable small combatants. Naval Fitters were first assigned to the Baltic Fleet, and a new naval unit was formed recently in the Pacific.

ASW is an important and growing mission for SNA as new and improved airborne sensors are deployed. A Bear F turboprop variant, designed for ASW missions, was introduced in 1970 and has since been upgraded. With a 5,000-kilometer radius and a sophisticated sensor suite, it enables the Soviets to extend the range and quality of their ASW searches.

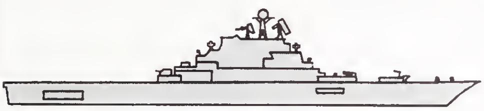
## *Surface Ship Comparisons*

### *USSR*

**New Class Aircraft Carrier**

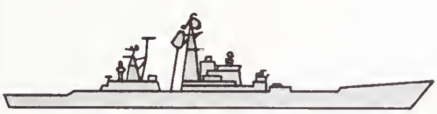
300 Meters (est.)
Displacement 65,000 Tons

**KIEV-Class Guided-Missile VSTOL Aircraft Carrier**



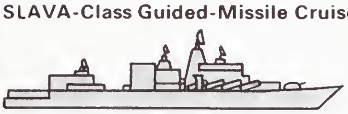
273 Meters
Displacement 37,100 Tons

**KIROV-Class Guided-Missile Cruiser**



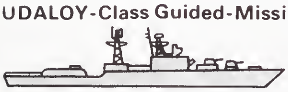
248 Meters
Displacement 28,000 Tons

**SLAVA-Class Guided-Missile Cruiser**



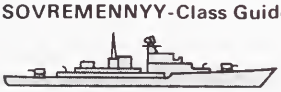
187 Meters
Displacement 12,500 Tons

**UDALOY-Class Guided-Missile Destroyer**



162 Meters
Displacement 8,000 Tons

**SOVREMENNYY-Class Guided-Missile Destroyer**



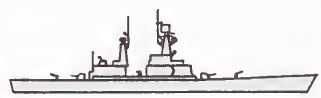
156 Meters
Displacement 7,900 Tons

### *US*

**NIMITZ-Class Aircraft Carrier**

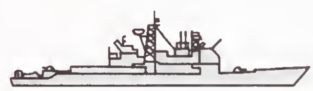
333 Meters
Displacement 91,400 Tons

**VIRGINIA-Class Guided-Missile Cruiser**



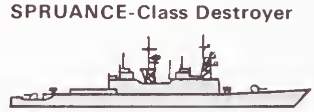
175 Meters
Displacement 11,000 Tons

**TICONDEROGA-Class Guided-Missile Cruiser**



170 Meters
Displacement 9,600 Tons

**SPRUANCE-Class Destroyer**



170 Meters
Displacement 7,824 Tons

**OLIVER HAZARD PERRY-Class Guided-Missile Frigate**

130 Meters
Displacement 3,605 Tons

For shipboard applications, a new ASW helicopter, the Helix, became operational in 1980. Now widely deployed in the Soviet fleets, the Helix has significantly greater range, speed, and payload than its Hormone predecessor.

**Naval SPETSNAZ Forces**

A smaller body of specially trained troops is also present in each fleet ara. Designated Special Purpose Forces, or SPETSNAZ, these troops are controlled by the Main Intelligence Directorate (GRU) of the Soviet General Staff and are trained to conduct a variety of sensitive missions, including reconnaissance and sabotage operations. A brigade-size unit is assigned to each of the four Soviet fleets.

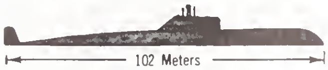
In wartime, small 5–12 man teams would be transported to a target area by aircraft, submarine, or surface ship and would be inserted immediately

## *USSR Attack Submarines*

**TANGO-Class SS**


| | |
|---|---|
| Armament: | Torpedoes, Possible ASW missile |
| Propulsion: | Diesel |
| Submerged Displacement: | 3,900 MT |
| Initial Operational Capability: | 1973 |

**CHARLIE II-Class SSGN**




| | |
|---|---|
| Armament: | Torpedoes, SS-N-9 antiship cruise missile |
| Propulsion: | Nuclear |
| Submerged Displacement: | 5,400 MT |
| Initial Operational Capability: | 1974 |

**VICTOR III-Class SSN**


| | |
|---|---|
| Armament: | Torpedoes, SS-N-16 ASW missile |
| Propulsion: | Nuclear |
| Submerged Displacement: | 6,300 MT |
| Initial Operational Capability: | 1979 |

**ALFA-Class SSN**


| | |
|---|---|
| Armament: | Torpedoes, SS-N-15 ASW missile |
| Propulsion: | Nuclear |
| Submerged Displacement: | 3,700 MT |
| Initial Operational Capability: | 1978 |

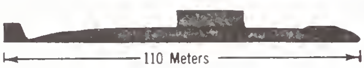
**OSCAR-Class SSGN**


| | |
|---|---|
| Armament: | Torpedoes, SS-N-19 antiship cruise missile |
| Propulsion: | Nuclear |
| Submerged Displacement: | 14,000 MT |
| Initial Operational Capability: | 1981 |

**KILO-Class SS**


| | |
|---|---|
| Armament: | Torpedoes |
| Propulsion: | Diesel |
| Submerged Displacement: | 3,000 MT |
| Initial Operational Capability: | 1980 |

**MIKE-Class SSN**




| | |
|---|---|
| Armament: | Torpedoes, ASW missile |
| Propulsion: | Nuclear |
| Submerged Displacement: | 9,700 MT |
| Initial Operational Capability: | 1983 |

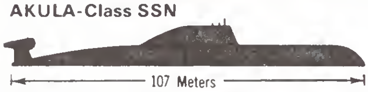
**SIERRA-Class SSN**


| | |
|---|---|
| Armament: | Torpedoes, ASW missile |
| Propulsion: | Nuclear |
| Submerged Displacement: | 8,000 MT |
| Initial Operational Capability: | 1984 |

**YANKEE-Class SSN**


| | |
|---|---|
| Armament: | Torpedoes, land-attack cruise missile |
| Propulsion: | Nuclear |
| Submerged Displacement: | 13,000 MT |
| Initial Operational Capability: | 1984 |

**AKULA-Class SSN**




| | |
|---|---|
| Armament: | Torpedoes, ASW missile |
| Propulsion: | Nuclear |
| Submerged Displacement: | 8,000 MT |
| Initial Operational Capability: | 1985; still in sea trials |

## *US Attack Submarines*

**LOS ANGELES-Class SSN-688**


| | |
|---|---|
| Armament: | Torpedoes, HARPOON antiship missiles, TOMAHAWK SLCM, SUBROC ASW rocket |
| Propulsion: | Nuclear |
| Submerged Displacement: | 6,500 MT |

**USS LOS ANGELES-Class is shown for comparison purposes. Other US attack submarine classes are STURGEON, SKIPJACK, SKATE, and PERMIT.**

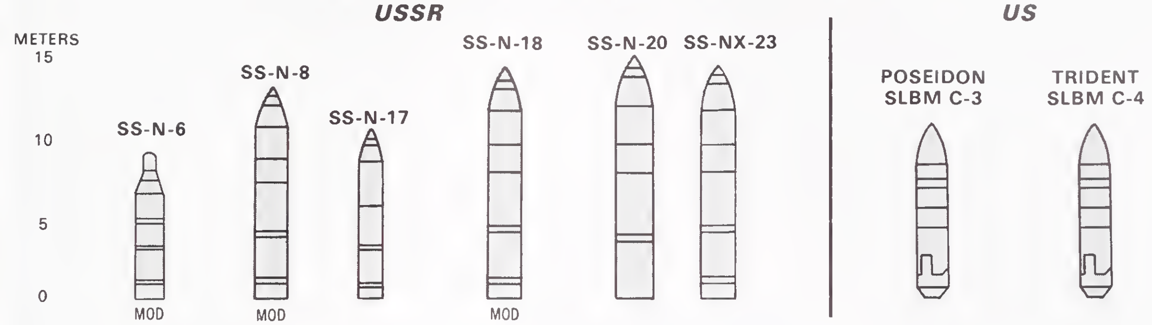
prior to hostilities. Their training includes parachuting, scuba diving, demolition, sabotage, surveillance, and target selection, as well as languages, such as English and French.

Once deployed, naval associated SPETSNAZ would conduct reconnaissance and tactical operations against a wide variety of naval targets, such as ship and submarine bases, airfields, command and intelligence centers, communication facilities, ports, and harbors, radar sites, and—of prime importance—nuclear weapons facilities. Though a small force, SPETSNAZ has the potential to achieve results disproportionate to its size.

### Soviet Merchant Fleet

Going beyond the strict categorization of military

### *Nuclear Submarine-Launched Ballistic Missiles*




| | SS-N-6 MOD 1 | SS-N-6 MOD 2 | SS-N-6 MOD 3 | SS-N-8 MOD 1 | SS-N-8 MOD 2 | SS-N-17 | SS-N-18 MOD 1 | SS-N-18 MOD 2 | SS-N-18 MOD 3 | SS-N-20 | SS-NX-23 | POSEIDON SLBM C-3 | TRIDENT SLBM C-4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RV's | 1 | 1 | 2 MRVs | 1 | 1 | 1 | 3 MIRVs | 1 | 7 MIRVs | 6-9 | In flight test | 10 | 8 |
| RANGE (KM) | 2,400 | 3,000 | 3,000 | 7,800 | 9,100 | 3,900 | 6,500 | 8,000 | 6,500 | 8,300 | | 4,000 | 7,400 |

SS-N-5s not shown

forces, the Soviet concept of seapower envisions the use of all its maritime resources, including the Merchant Marine and large fishing and research fleets, in support of state policy. Since World War II, the Soviet Merchant Marine has grown from a group of rusting coastal freighters to rank fifth in the world in numbers of ships and eighth in terms of dead-weight tonnage.

The growth of the Soviet Merchant Marine to some 1,700 ships has been carefully directed to create a fleet that can perform a commercially competitive peacetime mission and satisfy military logistics requirements in crisis or war. Continued Soviet attention to the military application of its maritime fleet is reflected in substantial investment in new ships and associated facilities that, in many cases, clearly surpass their demonstrated and projected commercial applications (see page 85).

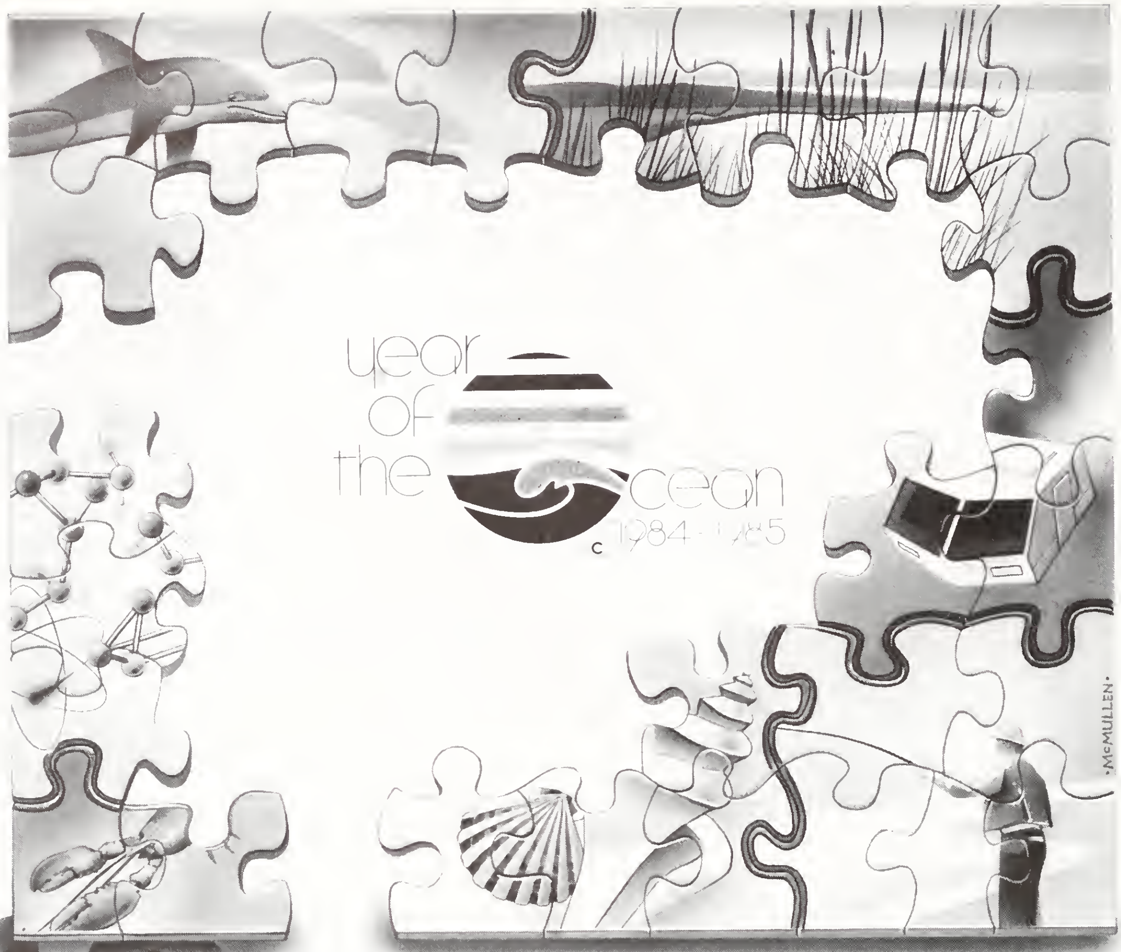
**Research and Development**

The Soviets support a wide variety of research and development efforts that stimulate an expanding industrial base oriented primarily toward military systems and construction.

In the area of naval technologies, the Soviets produce approximately 1,500 graduates annually. This is contrasted with the approximately 400 yearly graduates of the 10 major U.S. universities that offer a curriculum in shipbuilding technologies. Soviet naval research institutes, whose programs are directly applied to naval weapon systems, have experienced a steady annual growth since the early 1970s and are continuing to expand. Separate naval test facilities under continuous modernization and a growing fleet of more than 170 specialized naval research ships are also dedicated to the Soviet naval research and development (R&D) effort.

The Soviets have a large-scale program to acquire a broad range of Western technologies critical to the enhancement of Soviet naval weapons capabilities. This technology transfer allows the Soviets a preview of future Western military systems and enables them not only to reduce their own inherent R&D risks by exploiting proven Western designs but also to develop prospective countermeasures.

This R&D effort makes it likely that new weapons and sensors will evolve within the next 10 years in virtually every category of naval warfare.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# profile John R. Seesholtz

Portrait by Charles Kerins

# Oceanographer of the Navy

**by Paul R. Ryan**

John Seesholtz is a little like a strong anchor in a gale. He's holding fast in a very demanding job. A sturdily built man with a semi-crewcut that suggests a white-headed retirement, he hails from the mountain country around Reading, Pennsylvania, and is proud of it.

He is fond of recalling the time when his father once visited him in the 1960s at New London, Connecticut. The younger Seesholtz was assigned to an old diesel submarine of World War II vintage. The elder Seesholtz, now deceased, had been a miner in his younger years before becoming a successful businessman. After a tour of the old sub, the father remained uncharacteristically quiet for some two hours. Finally, as they were traveling home to Pennsylvania in the family car on a cold, blustery Sunday in January, the elder Seesholtz turned to his son and blurted out, "That reminded me of being in the mines. I thought that your being in the Navy would get you away from that kind of life."

It would—eventually. His son would rise to the rank of Commodore—one star—and be appointed Oceanographer of the Navy, a command that extends worldwide and includes the duty of Director of the Oceanography Division in the Office of the Chief of Naval Operations. The younger Seesholtz, however, loved his days in the "Navy mines."

At one point, early in his Navy career, Seesholtz was Commanding Officer of the *U.S.S. Dolphin*, the world's deepest diving submarine. "We carried out the deepest sonar operations conducted to that time, and learned a great deal about how sound traveled deep in the ocean. I still view this assignment as probably the most enjoyable time I've ever had," Seesholtz recalled.

Commodore John Richard Seesholtz, 52, graduated from the U.S. Naval Academy in 1956. The son of Mrs. G. Elizabeth and John F. Seesholtz, he has a brother David, a forest ranger at Mount St. Helens, Washington, and two sisters, Barbara Sparr of Reading, and Mary Ann Yeager of Green Hills, both in Pennsylvania.

"I spent about 8 years at sea before I got into oceanography. The first ship I was on went to Antarctica and I enjoyed it very much. There were a lot of things that I saw in the ocean that puzzled me. I wondered what the mechanisms were for certain physical phenomena."

In the 1960s, the Secretary of the Navy established a Navy doctoral program. Seesholtz applied and was accepted at the Massachusetts Institute of Technology, graduating in 1968 with a Ph.D. in Oceanography. "The doctoral program, which was similar to the one that Secretary of the Navy John Lehman has recently reinstated, was something that came along at the right time in my life. I think as a result I wound up being the Oceanographer." Seesholtz remembers that his student days included work with Henry Stommel, Erik Mollo-Christensen, and Walter Munk, all eminent scientists today. "The Woods Hole Oceanographic Institution/MIT graduate joint program agreement was signed about a month before I graduated," he recalled.

***My responsibilities include operational oceanography. This consists of about 70 activities worldwide.***

The voyage to Oceanographer of the Navy, arrived at on 14 October 1983, would include tours as a missile officer on a Polaris submarine, a special projects officer at antisubmarine warfare headquarters, and director of programs in underwater acoustics, ocean processes, the Arctic, and defense and missile research and development. It would also include attendance at several special service schools, such as the Technical Russian Course at the Defense Language Institute, Monterey, California, and the Senior Officers' Ship Material Readiness Course in Idaho Falls, Idaho.

Being Oceanographer of the Navy does not leave Commodore Seesholtz much time for leisure activities, the chief of which is probably talking about Oceanography. He is married to the former Marylee Gehris of Bernville, Pennsylvania, and has two children, a son Daniel, who is a Lieutenant (jg) in the Navy, and Amy, who lives at home in Alexandria, Virginia. Most mornings will find him at his desk in the U.S. Naval Observatory building about 7 a.m. It is unusual to see him leave much before 7 p.m.

There is a sign on the first floor of the Naval Observatory that states its mission: "To determine the positions and motions of celestial bodies, the motions of the earth and precise time. To provide the astronomical and timing data required by the Navy and other components of the Department of Defense for navigation, precise positioning, and command control and communications. To make these data available to other government agencies and to the general public. To conduct relevant research. To perform other functions or tasks as may be directed by higher authorities."

One of Commodore Seesholtz's tasks is to oversee the Naval Observatory where Vice President George Bush and his family live in a house on the spacious, flowering grounds. The Navy facility is situated on a tree-shaded hill on Massachusetts Avenue, in Washington, D.C. A security guard, on entering the grounds, insists on I.D., and is quite specific about following the yellow line to the Commodore's office, presumably so one does not end up in the Bushes' living room.

The Commodore has an attractive, functional office, and greets one with a hearty handshake. On a warm day he is inclined to take off his jacket and urge his visitor to do the same. There is a large leather couch and two comfortable matching chairs on one side of the room. At the far end is a large desk. Along one wall is a sizeable map of the world with a lot of red

dots marking it. There also is a blackboard and a conference table. Several ocean-related magazines adorn the coffee table before the couch. A stream of captains flow in and out.

This interviewer asks the basic question: What does the Oceanographer of the Navy do? "My responsibilities include operational oceanography. This consists of about 70 activities worldwide. The red dots on the map over there represent the major facilities around the world that supply not only oceanographic information to ships, but also meteorological information associated with the marine environment to operational aircraft.

"In Monterey, California, for example, we have the Fleet Numerical Oceanography Center, which receives data from our worldwide network. They, in turn, fashion global weather models, some of which are distributed to our individual ships. The Center also monitors antisubmarine warfare conditions, especially as they relate to physical ocean conditions. The Center provides such things as wave forecasts—useful in avoiding areas of really rough weather—and reports on storm systems. This Center will be the primary data processor for the N-ROSS* satellite we hope to have aloft by the end of the decade. This satellite will have four dedicated ocean sensors.

"Other important centers are located in Maryland (Polar Oceanography Center), Pearl Harbor, Hawaii, and Guam. The latter, for example, is responsible for typhoon forecasting. It's a joint program we operate with the Air Force. We provide the typhoon warning for the civilian populations in these areas as well as for our ships at sea.

"Our largest single activity, the Naval Oceanographic Office, is located at Bay St. Louis, Mississippi. Through the military Sealift Command, we direct 12 oceanographic vessels, plus 3 aircraft. Four of the ships at the present time are doing deep ocean surveys in the mid-Atlantic, two others are in waters off Oman and Indonesia, and two others are working in coastal areas.

"We also run a cooperative program with a number of Latin American and Asian countries. We provide the equipment, small boats, and technical expertise, and they provide the crew. As a result, we get data that is helpful in producing charts of harbors and coastlines and they get data that is useful for their economic development.

***If we see something that has applied characteristics, we will try to orient that program so that it answers some basic questions.***

"Most of our ships are engaged in classical hydrography and oceanography: measurements of temperature and chemical structure, biological inquiries, and bathymetric work. Our aircraft mainly support major fleet exercises and operation. They are capable of sampling large areas of the ocean surface by dropping bathythermographs* and then processing the data on-board."

Commodore Seesholtz also explained that he was responsible for "Project Magnet," which consists of obtaining the magnetic signature of the world at periodic intervals. This is particularly useful in naval air operations that have magnetic navigation requirements. In addition, the Naval Observatory, under Seesholtz's command, provides the National Clock Service. This means providing frequency standards for communication requirements and navigation systems. The Global Positioning System, for example, is very dependent on accurate time references.

Another activity of the Oceanographer is putting together nautical almanacs with information gathered from field observatories in Florida and Arizona. These almanacs form the primary reference for people doing celestial navigation—navigation with a sextant and star tables.

All told, Commodore Seesholtz estimated that there are approximately 5,000 people associated with oceanography in the Navy. Of these, about 4,000 are directly connected with naval oceanography programs, 2,000 of whom are enlisted men. "We have some 400 naval officers employed here, and some 300 at sea. Then there are from 500 to 1,000 enlisted men out in the fleet who work with our system. We're responsible for their training. There are about 1,300 to 1,400 civilians working with us, too, the great majority at the Naval Oceanographic Office in Bay Saint Louis. The balance are scattered throughout the system."

The Oceanographer of the Navy is largely concerned with "applied" oceanography. "Basic" research is the province of the Office of Naval Research under the Chief of Naval Research, Rear Admiral John Bradford (Brad) Mooney, Jr. (see page 12). "We coordinate with Admiral Mooney's people. Several of our people are actually assigned to duty over there. Their job is to coordinate and develop projects that have their root in basic ocean science. If we see something that has applied characteristics, we will try to orient the program so that it answers some basic questions. Much of this work is done under grants in universities, some in laboratories."

An example of applied

* Navy-Remote Ocean Sensing Satellite.

* An instrument that records temperature at various depths in the ocean, usually within a few hundred meters of the surface.

oceanography is the use of satellite sensors. Data that used to be gathered by aircraft and ships—about the fine-grain structure of the ocean in a particular area or where upwelling occurs—is now being gathered by satellite sensors. These sensors can give detailed information on Gulf Stream meanders or the structure of large-scale eddies. They also can pinpoint areas with particular dew-point characteristics at certain times of day—areas that are likely candidates for fog, information useful to the Navy.

"Right now, on a clear day, we can pretty much tell what the ocean surface conditions are. The N-ROSS satellite will enable us to determine sea-surface conditions in the presence of clouds. We also will be able to get wind speed and direction from it, along with significant wave height."

Commodore Seesholtz expressed a personal interest in remote sensing along with understanding the exchange of energy between the atmosphere and the ocean. "If you are going to get lengthy weather forecasts beyond, say, five days, then we need a much more complete understanding of the reactions between the atmosphere and the oceans. The Europeans have developed some skill in forecasting beyond five days. Of course, our National Weather Service is probably only interested in the livable parts of the United States and in coastal waters. But we are interested in a good part of the rest of the ocean because that's where we have to be able to operate. The fleets are scattered all the way from the Indian Ocean to the Pacific and Atlantic."

The topic of remote sensing prompted the Commodore to mention the flight of oceanographer Paul Scully-Powers on the space shuttle last October. This civilian employee of the Navy took some 2,500 pictures of the oceans while orbiting 190 miles in space, some of which disclosed details of circulation features not previously observed. Eddies were clearly visible, but it was not known whether they were a foot deep or 100 feet deep. "We're finding out that the ocean is more opaque than we thought. It's more difficult to see or discern anything than we realized. I believe too many are overly optimistic about being able to see through the ocean to the bottom," Seesholtz commented.

As mentioned previously, keeping on top of these activities leaves very little time for leisure. Friends say that the Commodore is active in local church and civic affairs. "He's the type of man you trust with looking after your house and garden when going on vacation," one neighbor confided. Another spoke of his interest in carpentry—"he likes to make fences and cabinets." Still another spoke of his dry humor, while recalling that the Commodore was the recipient of a mink teddy bear from an admirer (his wife) this past Christmas. This suggests that behind the daily mask of formal reserve exists another persona—impish at times and playful.

Most of the Commodore's time, however, is devoted to serious, high-level Navy business. It is he and his command that provide the fleet and its aircraft with important environmental data so that the U.S. Navy can better carry out its national security functions. As Seesholtz put it, being Oceanographer of the Navy "is a lot of work, but it's also very interesting—a fun job."

history

# The Sea and Soviet Maritime Policy

by Michael MccGwire

**EDITOR's NOTE: The following material has been excerpted, with Mr. MccGwire's permission, from the proceedings of a March 1981 conference sponsored by the Center for Study of the American Experience, The Annenberg School of Communication, University of Southern California. The author notes that although this "is not the *latest* analysis of what the Soviets are thinking, it [still] presents a reasonably balanced picture [in 1985]." For a more current assessment, please see Chapter 5 of *Soviet Military Objectives* by Michael MccGwire, Brookings Institution, Washington, D.C., in press.**

The Russian Navy is nearing its 300th birthday, and for the last 200 years or so it generally has been the third or fourth largest in the world. Russia used naval forces in the 18th century to gain control of the Baltic and Black Sea coasts, and four times between 1768 and 1827 she deployed sizable squadrons to the Mediterranean for a year or more. Three of these deployments took place during wars with Turkey, with ships being drawn from the Baltic Fleet to operate against the southern side of the Black Sea exits.

But thereafter, Russia increasingly found herself confronting more powerful maritime nations. In the Black Sea, Britain used her naval strength to prevent Russian gains at the expense of the failing Ottoman Empire; in the company of France, Britain intervened directly in what we call the Crimean War, extending her naval operations against Russia to the Baltic, White Sea, and Pacific, and the subsequent peace treaty forbad Russia a Black Sea fleet. Twenty years later in the eighth Russo-Turkish War, British pressure ensured that Russia did not gain control of the Straits. In the Far East, Russo-Japanese rivalry culminated in a disastrous war and the loss of two Russian fleets. And in 1918, the Western navies provided vital support to the forces of counter-revolution. As a consequence, Russia's naval policy was increasingly dominated by the need to defend four widely separated fleet areas against maritime powers who could concentrate their forces at will.

It is therefore wrong to suggest that Russia has only recently awakened to the significance of sea power. She used it in the past to her own advantage, and has more often seen its long arm used against her. Over the years she has committed very substantial resources to naval construction, and the major warship building program initiated in 1945 was the fourth attempt in 65 years to build up a strong Russian fleet. But national strategy involves setting priorities and balancing competing claims for scarce resources. Russia was predominantly a land power; the only threats to her territorial existence had come by land; the army was the basis of security at home and influence abroad. Naval forces were indeed required to defend against assault from the sea and to counter the capability of maritime powers to dictate the outcome of events in areas adjacent to Russia. But these forces were seen as an expensive necessity rather than a preferred instrument of policy. This ordering of priorities, and the army's domination of military thinking, persist today and are enshrined in the concept of a combined arms approach to military problems, including naval ones.

### Postwar Naval Buildup

The Second World War confirmed Russia's belief that ground forces were the basis of her national security. However, by the end of the war her most likely opponents were the traditional maritime powers, who had not only been responsible for the capitalist intervention during the Russian Revolution, but had recently demonstrated their capacity to transport continental-scale armies over vast distances of sea and to support their operations ashore. The likelihood of maritime invasion of the Baltic and Black Sea coasts was considered substantial. The Baltic gave access to the lines of communication with the Western front. The Black Sea would allow invaders to by-pass Russia's traditional defense in depth; and the rivers, instead of serving as defensive barriers, would provide invaders with easy access to Russia's industrial heartlands. In enemy hands, the Black Sea becomes a grenade in Russia's gut.

In 1945, Russia had a powerful army but lacked a battleworthy fleet, and the navy therefore received relatively high priority in the postwar reconstruction, with force requirements largely carried over from before the war. Under the new, 20-year naval construction program, no fewer than 1,200 submarines were to be built. They probably also planned to

build some 200 escorts, 200 destroyers, about 36 cruisers, 4 battlecruisers, and 4 aircraft carriers during this period, plus a mass of torpedo boats, gunboats, and subchasers, and some 5,000 aircraft for the naval air force. Large numbers, but of course nothing compared to the size of the combined Western navies at the end of the war, and even the submarines fall into perspective when divided among the four fleet areas. The prewar concept of defense in depth and coordinated attacks by air, submarine, and surface units was carried over. About 1,000 of the 1,200 submarines were intended for defense of the home fleet areas, and the carriers probably were intended to extend fighter cover in the Barents Sea and in the Pacific.

### Shift in Threat Perceptions

However, in 1954, as a consequence of the post-Stalin policy review, the Soviet leadership downgraded the threat of seaborne invasion and gave first priority to the dangers of a surprise nuclear attack by strategic bombers. The naval threat from the West was seen in more limited terms of nuclear strikes by carrier-borne aircraft, primarily against naval bases. This engendered a radical reappraisal of naval requirements and the decision to place primary reliance on long-range cruise missiles, which would be carried by small- to medium-sized surface ships, diesel submarines, and aircraft. The operational concept relied on the potential reach, the payload, and the accuracy of these weapons (which had yet to be developed) as a substitute for large numbers of weapon platforms. It appears to have been influenced by the demands of the domestic economy and the need to release shipbuilding facilities to commercial construction.

There was resistance within the Soviet Navy to these ideas, so Nikita Khrushchev brought the 45-year-old Sergei Gorshkov to Moscow to implement the decisions. The building of cruisers was checked in mid-course; the mass production of medium-sized submarines, then at 72 units a year, was sharply tapered to a halt; and while the destroyer, escort, and subchaser programs each ran its full course, their successor classes were put back four years. This represented a 60 percent cut in annual production tonnage, enabling substantial resources to be released from warship construction to the domestic economy. Seven of the 13 largest building ways were reassigned from naval use to the construction of fish factory and merchant ships. This shift of resources from naval to commerical construction was an important indication of Soviet priorities in use of the sea.

The new concept of operations was predicted on engaging enemy carrier groups within range of shore-based air cover. It envisaged coordinated missile attacks by strike aircraft, diesel submarines, and large destroyers, and it was planned that these newly designed units would begin to enter service in 1962. However, by 1958 the key premise that shore-based fighter defense would be available over the encounter zone had been rendered invalid by increases in the range of carrier-borne aircraft, which would allow U.S. carriers to strike at the Soviet Union with nuclear weapons from the Eastern Mediterranean and the southern reaches of the Norwegian Sea. To meet this threat from distant sea areas, it was decided to place primary emphasis on nuclear submarines, which would be able to operate in the face of Western surface and air superiority.

This involved another major change in naval building programs, and to understand the full implications, we must backtrack to pick up the task of strategic interdiction. Faced with the U.S. atomic monopoly, at the end of World War II the Soviet Union had to develop not only its own weapon, but also the means of delivering it. In regard to the latter the Soviets pursued three lines of development: the intercontinental missile, the long-range bomber, and the submarine. The Soviet Navy had a tradition of daring attacks on enemy ports, and the torpedo-firing submarine was the only system immediately available that had the range and payload to bring atomic weapons to bear on North America; a shallow-water burst in the approaches to New York or San Francisco was a significant threat. But here, also, there was parallel development of tried and innovative systems, with a nuclear torpedo probably being developed by 1954, and a ballistic missile being test-fired from a submarine in 1955. These were the precursors to four classes of submarine that began delivery in 1958, two of them nuclear-powered and two diesel, one of each type armed with ballistic missiles, the other relying on torpedoes. However, technical problems (the nuclear classes were noisy and the missile-armed classes had an unreliable weapon system), coupled with advances in American antisubmarine capabilities, meant that at least three of the four classes were unable to meet planned operational requirements.

### The Carrier Air Threat

Thus, by about 1958, there was a convergence of three separate developments: the apparent success of the Soviet intercontinental ballistic-missile program, which would become the main means of delivering nuclear weapons to America; the relative failure of the submarine strategic delivery systems; and the emergence of a new strategic threat to the Soviet Union in the shape of long-range nuclear strikes by carrier-based enemy aircraft. It was this combination that justified the reallocation of nuclear propulsion from the role of strategic delivery to that of countering the carrier, the role of strategic missile strike being taken away from the navy at about the same time. The missile-armed diesel submarine (SSG) programs were cancelled and, as an expedient, their long-range surface-to-surface missile (SSM) systems were used to reconfigure the nuclear-powered hull/propulsion units (originally

intended as ballistic missile submarines) as cruise missile-armed units (SSGN) for use against the carrier. Meanwhile, plans were made to double the production of nuclear submarines to ten boats a year, with deliveries due to begin in 1968, and to develop new methods of attacking the carrier, including a horizon-range submerged-launch cruise missile system with its own target location capability.

In this same period of 1957 to 1958, a need to extend the range of antisubmarine warfare (ASW) coverage beyond that provided by shore-based helicopters was identified, particularly in northern waters, where the Soviets assumed that U.S. Polaris submarines would patrol in due course. This led to the production of the *Moskva*-class of antisubmarine helicopter carriers.

**Reformulation of Soviet Policy**

This brings us to 1961: a year crucial to understanding contemporary Soviet policy, in which decisions arrived at barely 20 months before were reversed. In January of 1960, Khrushchev had announced the results of what appears to have been a thoroughgoing defense review, which included formation of the strategic rocket force (SRF), its designation as the primary arm of the nation's defense, a substantial reorganization of military research and development, and the cutting back of conventional ground forces. Given Khrushchev's faith in nuclear missiles and his belief that nuclear war would be suicidal, the new policy could only indicate a shift in emphasis toward the Western concept of nuclear deterrence, and away from the traditional reliance on balanced forces and a war-fighting capability.

But by October of 1961 the shift had been reversed, and, at the 22nd Party Congress, Marshall Malinovsky's speech clearly indicated a return to traditional military verities. Meanwhile, a thoroughgoing reappraisal of what was involved in fighting with nuclear weapons was begun, as was development of a whole series of consequential policies, including a restructuring of the ballistic missile programs.

There is now substantial evidence that this reversal of policy reflected a re-evaluation of the Western threat, engendered by the defense decisions announced by President John F. Kennedy shortly after he took office in January, 1961. These included a very sharp acceleration of the Polaris program and a doubling of the planned production rate of solid-fuel ICBMs, which would be deployed in underground silos, remote from centers of population. Perhaps equally important to Soviet threat perceptions were the crusading rhetoric of the new American administration, with its willingness to go any place and pay any price, and the detached logic of tough-minded academic strategists who were busy thinking the unthinkable and developing theories of limited nuclear war.

From the Soviet viewpoint, a significant aspect of the U.S. decisions was the apparent shift in emphasis from land-based to sea-based strategic nuclear strike forces: the rapid buildup of Polaris units coinciding with the entry into service of the large attack carriers (including the nuclear-powered *Enterprise*) ordered in the wake of the Korean War. These units could be expected to survive the intercontinental exchange and could therefore be held back in order to influence the outcome of the war. In particular, these forces could deny the Soviet Union the use of Western Europe as an alternative socio-economic base. Given the Soviet doctrine of deterrence through possession of a warfighting capability, this had major implications for the Soviet Navy's roles and missions. First, it would have to develop some means of countering these American systems. And second, it would be necessary to develop matching assets so as to deny the United States a unilateral advantage, in the event it could not be countered.

This second requirement meant that, after all, the Soviet Union would have to build up a force of nuclear-powered ballistic missile submarines (SSBN), but this could be done only at the expense of the hull/propulsion units originally intended for other roles, including that of countering the carrier. The latter mission would remain practicable, although at a lower level of effectiveness. Polaris, however, presented a problem of a different kind.

**The Anti-Polaris Response**

There were three possible ways of directly countering Polaris: area exclusion, trailing, and ocean search/surveillance. The last two would require development of new systems, but a start could be made on the incremental process of excluding Polaris submarines from the more threatening sea areas, by trying to raise to unacceptable levels the probability of their detection. This would involve an extension and elaboration of the operational concepts that had been successfully developed for defense of the Soviet offshore zone, but would require additional, purpose-designed antisubmarine warfare (ASW) forces.

This explains the Soviet Navy's shift to forward deployment in the early 1960s. It took place in two stages. The initial response (lasting five years) extended the outer defense zone to the 1,500-nautical mile (nm) circle from Moscow. This covered the threat from carrier strike aircraft as well as the early Polaris systems, and took in the Norwegian Sea and the Eastern Mediterranean. The interim response, starting in 1967, was a slow process of consolidating the newly established defense zones, while extending the area of naval concern to take in the 2,500-nautical mile circle of threat. This included the eastern half of the North Atlantic and the northwestern part of the Arabian Sea. There was a progressive buildup in the number of ships on forward deployment and in ship-days deployed until the period from 1972 to 1973, when both levelled off.

Meanwhile, the major

emphasis in surface ship capabilities was switched from anticarrier to antisubmarine systems, in part by the major conversion of two existing classes (SAM Kotlin and Kanin) and in part by modifying the design of new construction programs, one currently building and the others projected. For example, the 12-ship *Moskva* program of helicopter-carrying antisubmarine cruisers was cancelled (because the cruiser was too small to be operationally effective in the new concept), and its weapon systems were used to switch the *Kresta* from anticarrier (*Kresta I*) to antisubmarine (*Kresta II*). The *Moskva* was replaced by the *Kiev* ASW carrier, at twice the size.

As originally planned, it was probably hoped that 10 years would be sufficient to develop a range of measures that, beginning in 1972, would allow some kind of final response to Polaris along all three lines of attack. However, not only were these hopes unduly optimistic, but other developments had meanwhile prompted a shift in operational priorities.

**The Nuclear Reserve Goes to Sea**

The most significant development was the relative failure of the SS-13 land-based, solid-fueled ICBM during 1967 and 1968. It seems likely that the Soviets had intended to develop this as a mobile system, so that it could serve as the main element of the national strategic reserve. Faced by this failure, it would appear that the Soviets chose the alternative of achieving mobility and concealment by putting the strategic reserve to sea aboard the Delta-class SSBN, due to begin delivery in 1973. However, to ensure security, the SSBNs would have to operate in protected waters, which meant that the planned range of the SS-N-8 missile would have to be extended considerably. The resultant lengthening of the missile would explain the improbable humpback characteristics of the Delta-class.

At about this time, the American press reported that the U.S. Navy was intending to develop two new classes of submarine for operations against Soviet SSBNs, one very fast and the other very silent, that would enter service at about the same time as the Delta. This focused Soviet attention on the force's security and led to the concept of deploying submarines in defended ocean bastions in the Greenland and Barents Seas and in the Sea of Okhotsk. Meanwhile, as more antisubmarine systems became available to the Soviets aboard new surface ships, submarines, and aircraft, it must have become increasingly clear that these traditional methods had inherent limitations against Polaris. This led to a shift in ASW emphasis away from the Eastern Mediterranean and Arabian Seas, to extending the inner defense zones of the Northern and Pacific Fleet areas, and to providing them with watertight defenses.

The shift in operational priority to protecting the SSBN bastions generated a fundamental change in the design criteria for distant-water surface units. Previously, the emphasis had been on weathering a preemptive attack long enough for the surface units to be able to strike at Western carriers and Polaris submarines, after which the surface units were expendable. Now, the security of the SSBN bastions had to be ensured for the duration of a protracted war. Surface ships, therefore, had to be capable of the sustained operations needed to gain and maintain command of a large sea area such as the Norwegian Sea, and this required long endurance, large magazine loads, and an underway replenishment capability. Establishing command would be facilitated by seizing key stretches of coast. In the Pacific this could involve the Japanese side of the two southern straits that give access to the Sea of Okhotsk, and might even extend to the whole northern coast of Hokkaido. In the Norwegian Sea, the requirement could include key islands as well as stretches of the Norwegian coast.

**Scaling Up the Surface Forces**

To meet these new requirements, the Soviets decided they would have to scale up the whole surface force, roughly doubling the size of all major surface types. The traditional destroyer-sized unit of about 3,500 tons (*Krivak*) was redesignated as an escort toward the end of the 1970s. The new destroyer types that began delivery in 1980 (*Sovremmeny* and *Udaloy*) are about 7,000 to 8,000 tons, larger than the previous generation of light cruisers. The new light cruiser class is expected to be 12,000 to 13,000 tons, and the *Kirov*-class heavy command cruiser (or battle cruiser) is over 20,000 tons. There has been a similar scaling-up of amphibious construction. This represents a major increase in the allocation of resources to naval shipyards; the *Kirov* program required the return to the Soviet Navy of shipyard facilities that had been in civilian use since the mid-1950s.

These new classes appear to have been included in the Ninth Five-Year Plan approved by the Twenty-fourth Party Congress in the spring of 1971. The plan also would have included the various submarine programs, including the Oscar-class of SSGN, (which displaces some 16,000 tons and carries the new mach-2.5 long-range SSM system fitted aboard *Kirov*), and the very large Typhoon-class of SSBN, which one must assume to have been purpose-designed to operate from the protection of Soviet home waters. However, the Soviet Navy still did not consider these substantial increases sufficient to meet the new demands being placed upon it, and took its case to a wider audience by means of articles in *Morskoj sbornik* that have become known as "the Gorshkov series." This debate had other ramifications that will be touched on later, but a major strand concerned the importance of general-purpose forces, particularly in the submarine-support role, and the need for a greater diversity of surface ship types, the characteristics of which should provide for long range at high speeds.

The in-house argument would have focused on the specifics of the threat to the

Soviet SSBN. The direct threat would come from U.S. nuclear-powered attack submarines, but the SSNs' success would depend on suppression of Soviet ASW defenses by supporting U.S. surface forces. The Soviet Navy would have had to assume that U.S. carrier groups would be deployed in support of their SSN, whereas Soviet shore-based air forces would cease to be available after the initial nuclear exchange. Without this air component, there would be no certainty that the Soviets would be able to prevent the carrier groups from penetrating the outer defense zones. It could be assumed that U.S. carriers would seek to establish command of the surface and the air, denying their use to Soviet ASW forces; that they would harry the defending SSN; and that they might even become directly involved in hunting down Soviet SSBNs. If the Soviet Navy were to prevail against this kind of force, it would need a comparable capability, including effective sea-based air forces.

Presumably, it was the inherent plausibility of this scenario that allowed the Soviet Navy to win at least part of its case, and it seems that by mid-1974 authority was given to go ahead with the design of a large air-superiority carrier that would enter service in the second half of the 1980s. It may also have been at this stage that the second of the new destroyer-sized ship classes was authorized, in order to allow for task specialization between classes.

### The Search for Naval Adequacy

Presently, the Soviet Union is embarking on yet another attempt to reshape its navy to meet changing requirements. The underlying theme, however, remains the same, and the allocation of resources to naval construction reflects the Soviet perception of a threat of assault from the sea.

After World War II, we saw first the mass-construction programs designed to meet a misperceived threat that was incorrectly inferred from the capitalists' war-inflated navies and from a Marxist prognosis of history. This was followed by savage cuts in shipyard allocations when the likelihood of seaborne invasion was realized to be low. Then there was heavy investment in nuclear submarine construction facilities, responding to the new and correctly perceived threat from carrier-borne strike aircraft, and to the need to oppose them in Western-dominated waters. The 1961 period not only included the addition of Polaris to the immediate problem, it included a more complex formulation of threat as the Soviets thought through the implications of warfighting with nuclear weapons and of sea-based systems being withheld from the initial intercontinental exchange. And then in 1968, it was decided to put the national nuclear reserve to sea, generating a qualitatively new need to ensure the integrity of home waters in the north and the Pacific.

### The Chinese Dimension

These naval requirements all stemmed from the threat of war with the West, but by the end of the 1960s there was added concern about the growing possibility of war with China. In such an event, it had to be assumed that the Trans-Siberian railway would be cut and that the Far Eastern front would have to be supplied by ship, either via the Red Sea or through the Persian Gulf. These shipments would require protection from the Chinese submarine force (the third largest in the world), and the threat of attack could reach back to the Arabian Sea. This increased the strategic significance of the Indian Ocean, more than compensating for the shift in emphasis away from the countering of Polaris in that area.

### Peacetime Role of Naval Forces

The Soviet Navy's move forward in strategic defense brought with it political opportunities for exploiting the presence of Soviet forces in distant waters, but even here, wartime concerns assumed importance. Underlying the pattern of Soviet naval diplomacy over the last 15 to 20 years, we can infer four types of objectives, each involving a different level of risk and degree of political commitment. At the high end of the scale is the requirement "to establish a strategic infrastructure to support war-related missions," an objective that has been the primary motive for a broad span of decisions ranging from promoting a coup in a client state, to acquiring base rights by barely concealed coercion. The pressure on Egypt from 1961 to 1967 to provide naval support facilities is a good example. Another is base rights in Somalia. The latter were originally intended to support the development of a counter-Polaris capability, but by the early 1970s, the concern had extended to protecting the sea lines of communication and to securing the entrance to the Persian Gulf.

At the low end of the scale of political commitment is "protecting Soviet lives and property." In between these extremes is the general objective of "increasing Soviet prestige and influence," which encompasses a wide span of activity from showing the flag and port-clearance operations to providing support for revolutionary elements or to regimes threatened by secessionist elements. The Soviets are prepared to commit significant resources to this objective, but while the propensity for risk-taking has risen steadily, the underlying political commitment remains strictly limited.

Overlapping this general influence-building objective is the more restricted one of "countering imperialist aggression." Despite much bombast, it appears that when it comes to major confrontation with the West, Soviet political commitment is low. After 15 years we have no hard evidence of Soviet readiness to actually engage Western naval forces in order to prevent them from intervening against a Soviet client state, although the Soviets sometimes have positioned themselves as if to do so.

What we do see is progressively greater involvement by the Soviet Navy


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in the provision of logistical support, both before and during Third World conflicts. However, as an instrument of overseas policy, the navy's role remains secondary. The primary instruments are arms supply; military advice and training; the transport of men, munitions, and equipment by merchant ship and long-range aircraft; and direct participation by combat troops of revolutionary states such as Cuba and Vietnam. The main role of the Soviet Navy is to provide protection against interference by local states, and to serve as an assurance of Soviet commitment.

**The Sea in Soviet Foreign Policy**

Is there some grand Soviet design driving a coordinated ocean policy in support of overseas objectives? The short answer appears to be no, but here we must distinguish between the operational aspects and the setting of objectives. The military-style organization of the merchant, fishing, and research fleets means that they can be used in peacetime for naval support tasks such as replenishment, forward picketing, and intelligence gathering. There are also geostrategic advantages to be gained with respect to a worldwide maritime infrastructure, actual or potential.

However, the long-term interests of the military, merchant, and fishing fleets often diverge. The buildup of the fishing fleet stemmed from the Soviet decision in the late 1940s that fishing is a more cost-effective source of protein than farming. The buildup of the merchant fleet reflected the post-Stalin shift toward trade, aid, and arms supply in the middle 1950s, and the consequential need to earn hard currency and avoid dependence on foreign shipping. At the same time, the Soviet Navy's shift to forward deployment reflected the new threat to the Soviet homeland from distant sea areas. Inevitably, there is some conflict among these different interests, as could be seen at the Law of the Sea negotiations. Only the merchant fleet, which brings in military supplies, takes out local commodities such as bauxite and rubber, and is both a well-disciplined and a pacific instrument, consistently serves the more general foreign policy goals of increasing the Soviet Union's share of world influence. To that extent, it can be seen as the principal maritime instrument of Soviet overseas policy.

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## EEZ Symposium

**DATE:** October 2–3, 1985

**CO-SPONSORS:** National Oceanic and Atmospheric Administration, Department of Interior, Smithsonian Institution.

**TITLE:** Exclusive Economic Zone: Exploring The New Ocean Frontier.

**LOCATION:** Baird Auditorium, Smithsonian Institution, National Museum of Natural History, Washington D.C.

**CONTACT:** Millington Lockwood, NOAA/National Ocean Service, Exclusive Economic Zone Program Office, 6001 Executive Boulevard, Rockville, MD 20852 Phone 301-443-8128.

## Addendum and Correction

The chart of state laws relating to marine archaeology that appeared on page 5 of the Spring 1985 issue of *Oceanus* was prepared by Anne Giesecke.

The object being examined by a diver in the photograph on page 19 of the same issue was incorrectly identified as a coral. It is a sponge.

## 115th Annual Meeting American Fisheries Society

The 115th annual meeting of the American Fisheries Society will be held in conjunction with the 75th annual meeting of the International Association of Fish and Wildlife Agencies in Sun Valley, Idaho, September 7–12, 1985.

Special session topics include Application of Remote Sensing to Fisheries, Fish Habitat Relationships, Rehabilitation of Depressed Salmon and Steelhead Runs in the Columbia River Basin, User Group Conflicts—Economic Elements and Social Impacts, Water Quality Concerns—Real or Perceived, Riparian Ecosystem Management, Competitive Fishing—Challenges and Potential Impacts, Computer Utilization in Hatcheries, Problems with Gas Supersaturation, Tribal Governments as Co-managers of Fisheries Resources, and Gear Evaluation in Difficult Habitats. Full-day workshops are planned on Stock Assessment and Fisheries Education. Several contributed paper sessions will be held, including Freshwater and Marine Fisheries Management, Fish Population Dynamics, Pollution and Toxicology, Physiology and Genetics and Fish Ecology.

All program-related questions should be directed to R. G. White, 1985 AFS Program Chairman, Montana Cooperative Fishery Research Unit, Biology Department, Montana State University, Bozeman, MT 59717 (telephone 406-994-3491). Questions regarding meeting facilities and arrangements should be directed to Jim Keating, Arrangements Coordinator, 5203 Hill Road, Boise, Idaho 83703 (telephone 208-342-4401).

concerns

# The 1984 Argentine-Chilean Pact of Peace and Friendship

In 1984, Argentina and Chile concluded a Treaty of Peace and Friendship that has important economic, political, and strategic implications for the southernmost part of the Americas. Argentine President Alfonsín claimed that the treaty is a broad step toward "peace, integration, and disarmament in Latin America." There are nonetheless difficult obstacles that must be overcome if the ambitious aims of the treaty are to be realized.

### Historical Problems

The treaty is the result of arduous, protracted efforts by both countries to resolve many problems that had long soured their relations. Competition between Argentina and Chile for position and influence dates from the beginning of national independence in the early years of the last century. A boundary treaty between the two states in 1881 embodied a political compromise for the southern reaches of South America and established a legal framework to stabilize the compromise.

The 1881 treaty delineated the entire frontier between Argentina and Chile, and in general terms has been mutually accepted for the last 100 years. Moreover, in the south, the treaty played an important role in helping stabilize the respective distribution of land and maritime areas between Argentina and Chile. In essence, a commitment to a mutually accepted legal framework helped moderate political competition.

But ambiguities and uncertainties in the 1881 treaty became increasingly serious over time, as continuing political competition and mistrust between the two states weakened the good will generated by the original compromise. On several occasions, political differences threatened to degenerate into armed clashes and at

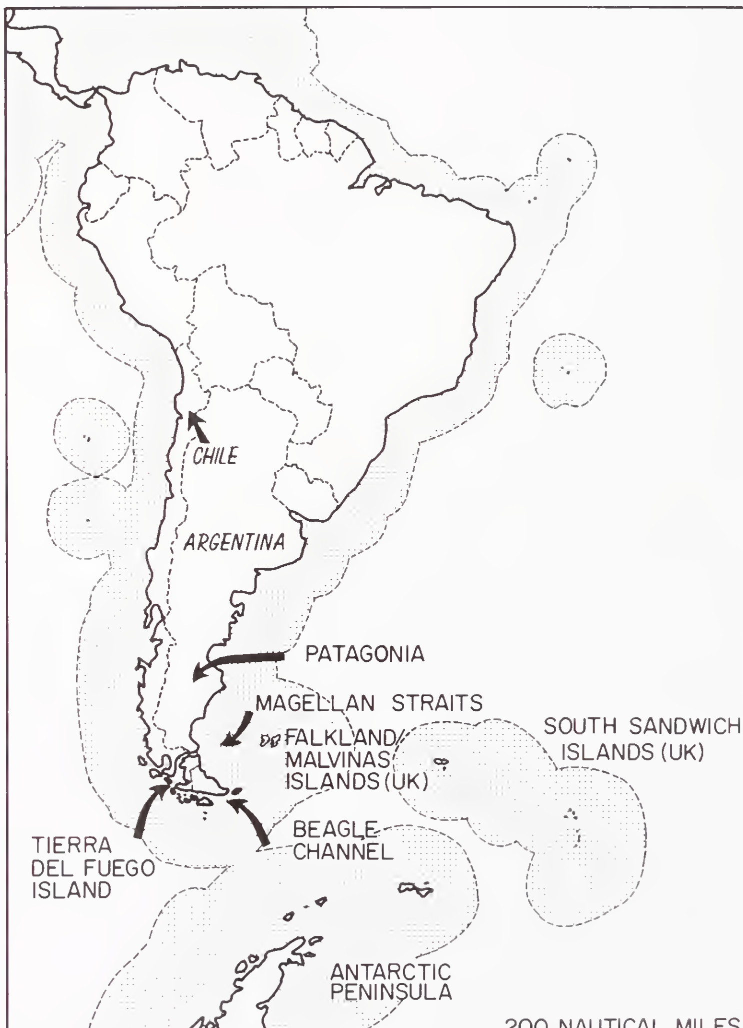


*Figure 1. The recent treaty between Argentina and Chile settles disputes over the Beagle Channel and the Straits of Magellan, and may affect the Falklands/Malvinas Islands and claims to Antarctica.*

times bordered on war.

The vagueness of the 1881 treaty spawned two pressing boundary disputes, which the 1984 treaty attempts to resolve. First, the 1881 treaty did not specify which country possessed the eastern mouth of the Strait of Magellan nor the ocean zone that the mouth of the strait would generate in the Atlantic Ocean. Second, the 1881 treaty did not clearly establish the boundary

between the two countries at the eastern end of the Beagle Channel. Here too, uncertainty about the boundary led to a related dispute about the ownership of offshore zones.

**Strategic Importance**

The area at the tip of South America's Southern Cone (Figure 1) encompassed by the 1984 treaty is resource-rich and strategically vital. These facts have conditioned prospects for conflict and cooperation, and have greatly complicated resolution of outstanding problems, which successive policy makers have been coping with for more than a century. At the same time, the very importance of the area will heighten the achievement of the new treaty, should it prove a viable solution.

The longstanding Beagle Channel dispute between Argentina and Chile has involved ocean areas that both parties have regarded as strategically important, in part because ownership of these areas would affect their respective Antarctic claims and their access to the cold continent. Both states very nearly went to war over the issue in 1978, which triggered involvement by the Pope in the dispute and eventually led to the 1984 treaty.

The Argentine-British dispute over the Falkland/Malvinas Islands has likewise festered for more than a century, and culminated in war in 1982. The war in fact steeled what had been wavering British resolve to remain in the islands. However, the proximity of considerable Argentine military power has since obliged Britain to adopt a "fortress Falklands" policy as long as it is unwilling to negotiate the issue of sovereignty with Argentina. Postwar Argentine responses, including a continuing air and naval buildup and persistent claims to sovereignty over the islands and adjacent ocean areas, also have contributed to the militarization of the Falklands and their offshore areas.

In 1962, Britain did redefine the Falkland Islands and dependencies to exclude British Antarctic territories, so that two separate administrative units replace the previously unified administration of these territories. Hence, a transfer of the Falklands to Argentine sovereignty would not affect British Antarctic claims. Nonetheless, the renewed British commitment to remain in the Falklands Islands has forged new bonds between the Falklands and the contiguous British Antarctic territory. This in turn complicates the longstanding problem of the overlapping Antarctic claims of Argentina, Britain, and Chile.

In the South Atlantic, heightened involvement of outside powers via the Falklands issue has threatened to awaken latent conflicts in this strategically located ocean basin. Britain's direct involvement and eventual victory in the 1982 Falklands war included reliance on Ascension Island in the middle of the ocean basin, and the United States siding with Britain against Argentina. Soviet involvement in the 1982 war was minimal, although offers of military equipment have been made to Argentina and the Soviet Union is well entrenched in both Angola and Mozambique, which border, respectively, the South Atlantic and Indian Ocean portions of the strategic shipping route around South Africa.

Chile has regarded any Argentine pretensions to share in control of the Strait of Magellan as directly challenging its vital national interests. Chile holds that its control of this important interoceanic waterway is a central element in the 1881 treaty compromise and is essential for its national security. In the last decade, however, competing interpretations of ownership of strategic areas offshore the Atlantic mouth of the Strait of Magellan have proliferated. Depending on the particular formulation, Argentina and Chile each claimed control over the eastern mouth of the strait as well as a 12-mile territorial sea and a 188-mile exclusive economic zone (EEZ) in the Atlantic, fronting the mouth of the strait. A Chilean EEZ would nearly reach a British Falklands' EEZ, to the dismay of Argentina.

The Strait of Magellan issue also complicated peaceful resolution of the Beagle Channel problem. Prior to the 1984 treaty, which provides an apparent legal solution to both matters, Argentina and Chile expected that any resolution of the Beagle Channel problem would merely set the scene for reopening the interlocking Strait of Magellan issue. A package deal or compromise resolving both issues simultaneously was consequently regarded as necessary, which contributed to the protracted, complicated nature of the negotiations.

**Economic Importance**

Argentina and Chile are well endowed with offshore resources, and the enclosure of these resources by extended territorial seas and exclusive economic zones promises significant economic development. Both Argentina and Chile have sizeable oil and gas reserves, including scattered distribution offshore. All of the Chilean oil production has been concentrated in the Magellan region in the far south, and since 1980 the majority of this production has occurred offshore in the large bay enclosed by the eastern entrance of the Strait of Magellan. The Magellan oil basin extends onshore to the north and south of the Strait of Magellan as well, and also offshore to the east into the Atlantic. Gas production, in contrast, has mostly occurred on land because of technological and transportation constraints.

Tension between Argentina and Chile increased in the late 1970s, when Argentina offered exploratory drilling concessions to foreign oil firms in the disputed area of the Atlantic ocean to the east of the Strait of Magellan, and also laid an offshore gas line from Tierra del Fuego Island to the mainland across the same disputed area. The 1984 Argentine-Chilean treaty allocated these previously disputed offshore areas to Argentina.

The unsettled political future of the Falkland Islands has slowed realization of offshore resource exploitation there as well. With the continuing diplomatic impasse over the Falklands, it seems unlikely that major international oil companies would make a sustained financial commitment to exploration and exploitation of offshore oil, even though the potential appears promising. Rational exploitation of the Falklands' fisheries has likewise been complicated by the ongoing diplomatic confrontation with Argentina. Argentina also has been concerned that a continued British presence in the Falklands would be economically strengthened through exploitation of living and nonliving offshore resources, in addition to allegedly depriving Argentina of its rightful patrimony.

Southern Cone fisheries are important both regionally and globally. Chile and Peru are the Latin American leaders in fisheries, with catches of about 4 million tons each in 1983 placing these two nations among the 10 leading fishing countries of the world. Mexico and Brazil are the third and fourth largest fishing states in the region, followed

by Argentina, which has caught less than 600,000 tons annually in recent years. In the case of Argentina, estimates of the maximum sustainable yield are well over 2 million metric tons annually, so the current yield may be as little as one-third of the potential. Moreover, these estimates of sustainable yield do not include the krill fishery in Antarctic waters, which Argentina and Chile are well situated to participate in because of large krill concentrations in the vicinity of the Antarctic peninsula (Figure 1).

**The 1984 Treaty**

After six years of bilateral negotiations and with the mediation of the Pope, Argentina and Chile signed the Treaty of Peace and Friendship on November 29, 1984. Since Argentina has been under civilian democratic rule from late 1983, approval of the treaty required protracted debates and involvement of both the executive and legislative branches of government. The electorate was involved through a referendum. A large majority of those voting (77%) approved the treaty, and the treaty also has been approved by both houses of the Argentine Congress, which completes the ratification process. In April 1985, the Chilean military junta ratified the treaty as well.

Articles 1 through 6 of this new treaty attempt to consolidate, formalize, and extend political understanding between Argentina and Chile. The two parties pledge to resolve their disputes amicably and to abstain from the use or threat of force in their bilateral relations. Elaborate conflict resolution measures are outlined in the treaty's Annex No. 1.

Articles 7 through 9 specify the complicated provisions regarding the maritime delimitation in the Beagle Channel area (Figure 2), and Article 10 contains the compromise reached between the two parties about the eastern mouth of the Strait of Magellan, in which Argentina implicitly denounces previous claims to participate in managing the strait and also pledges guaranteed access to all flags through its waters to and from the Strait of Magellan. For its part in the compromise, Chile is prevented from gaining a territorial sea and EEZ to the east of the Strait's mouth, to which it might otherwise have been entitled.

Article 12 covers the creation of a permanent binational commission for intensifying

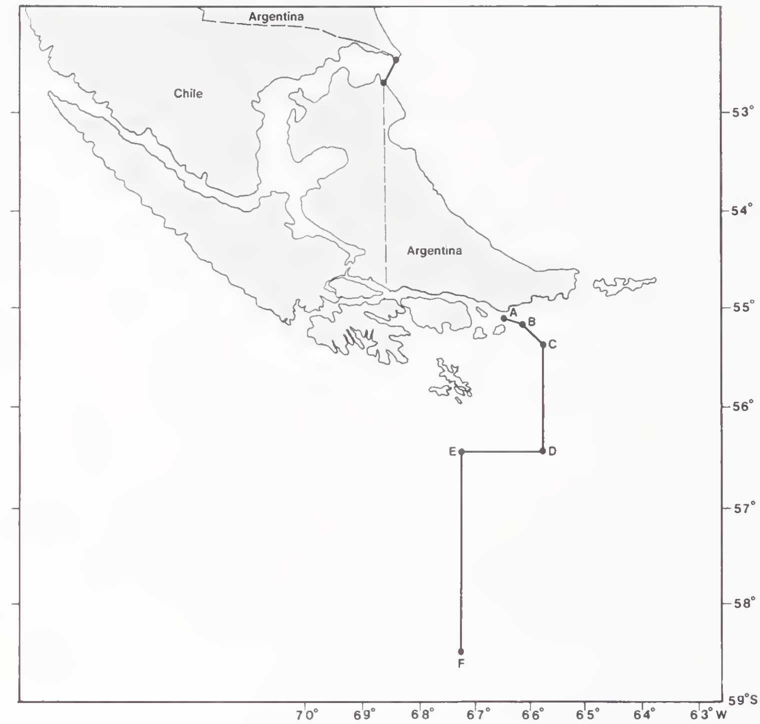


*Figure 2. The 1984 treaty establishes a firm boundary across the mouth of the Strait of Magellan, and a firm maritime boundary (A through F) in the Beagle Channel region.*

economic cooperation and physical integration. These cooperative measures are to include the overall economies of both nations and not just the extreme south.

**Implications of the 1984 Treaty**

While the 1881 Boundary Limit Treaty resolved then pressing boundary disputes, it could not help settle conflicts that arose afterwards. The Beagle Channel issue became increasingly acrimonious, and contending bilateral claims to Antarctica later arose. The Strait of Magellan was a pillar of stability embedded in treaty law. However, bilateral differences threatened to unravel the 1881 settlement and undermine the stability of the Strait's position. In essence, the 1984 treaty aspires to reinforce the stability of the longstanding legal pillar and to erect a new one, the Beagle Channel area, to complement the Strait of Magellan, replacing a somewhat shaky legal pillar with two sound ones.

The comprehensive nature of the treaty offers a framework for resolving past problems and moving toward greater cooperation, but the troubled history of Argentine-Chilean relations makes it difficult to be optimistic about relations between the two countries. The treaty's future will be enhanced if the initial steps taken toward economic integration gather momentum. Indeed the economic and political conditions appear as propitious as any in recent memory for longlasting improvement in bilateral relations.

The treaty does not purport to resolve the conflicting Antarctic claims of the two parties. However, the treaty may help isolate and lessen the importance of the Argentine-Chilean dispute involving Antarctica. The elaborate conflict resolution procedures of the treaty are to encompass bilateral differences over Antarctica. Some of the navigational provisions of Annex No. 2 involve navigation to and from Antarctica and could help reassure both parties that their access will not be threatened. Nonetheless, resolution of the Beagle Channel dispute had been complicated because both parties feared that any settlement there would prejudice their respective Antarctic claims. While the treaty is not to affect Antarctic claims, the Cape Horn meridian (line E–F of Figure 2), if extended to the South Pole, would cut through the Antarctic peninsula where Argentine and Chilean claims overlap. Even were the conflict resolution procedures of

the treaty to help resolve bilateral differences over Antarctica, Argentine and Chilean disputes with other nations, including Britain, over claims to Antarctic territories, would remain.

The 1984 treaty may also affect the Falkland/Malvinas Islands, although there is no mention whatsoever of the islands in the treaty. Adolfo Gass, President of the Argentine Senate's Committee on Foreign Relations, explicitly linked the treaty to the Falklands/Malvinas issue. He declared that resolution of boundary disputes with Chile would "free the hands of Argentina" to concentrate on regaining sovereignty over the Malvinas Islands from Britain. Just prior to signing the treaty, Argentine President Alfonsín likewise declared that the treaty between Argentina and Chile would "open the definitive possibility of working together for Argentine sovereignty over the Malvinas Islands." Chile, however, has maintained good relations with Britain and will surely wish to continue this relationship in the post-treaty setting. Post-treaty frustration in this respect for Argentina might trigger a new round of accusations, similar to those during the 1982 Falklands war, about Chilean collaboration with Britain.

At the same time, the new atmosphere of political entente and economic cooperation between Argentina and Chile presents Chile with an incentive to distance itself from the British presence in the Falklands. British expectations that Chile will lend important political and economic support for the British presence in the islands may be as misplaced as counterpart Argentine expectations.

One important positive development is that the new democratic government in Argentina, while reaffirming Argentine sovereignty over the Falklands, has emphasized that it will rely exclusively on peaceful methods of resolving the conflict. Herein lies an opportunity for new Anglo-Argentine negotiations and reconciliation of the interests of all concerned.

Some broader implications claimed for the treaty should be noted, although only time will tell if the flush of optimism following signature of the treaty will be warranted. Whether justified or not, new hope has been inspired for the peaceful resolution of some other Latin American conflicts. A popular impression throughout the continent is that since this intransigent dispute could be resolved peacefully, so too can other regional disputes. A related view is that papal mediation, having assisted conclusion of the 1984 treaty, now constitutes an important new method for resolving regional disputes.

Caution should temper such expectations. Argentina and Chile very nearly went to war in 1978 over the Beagle Channel issue, and it was only as an outgrowth of this scare that the current negotiations were undertaken. Similarly, only the failure of all conventional negotiating methods led to involvement of the Pope, and the 1984 treaty is the only successful example of papal mediation in modern times. Hence, papal mediation may not be successfully replicated in other circumstances, particularly since mediation depends on the good will of the states involved, which is conspicuously absent in numerous regional disputes.

Even the elaborate conflict resolution system contained in the treaty may not work in practice. Previous Argentine-Chilean conflict resolution procedures have appeared even more promising (for example, the provisions in 1902 for binding arbitration with a pre-established tribunal and in 1972 for binding judicial settlement through the International Court of Justice). Yet, these measures did not prove effective in resolving specific disputes. Similarly, there is a plethora of legal mechanisms for resolving Latin American disputes, but disputes continue to proliferate.

Important implications for arms proliferation and use may be associated with the treaty as well. Both Argentina and Chile have been prominent in the ongoing Latin American arms buildup and both have recently experienced military confrontation (with each other in 1978) or war (Argentina with Britain in 1982). Immediately before, during, and after the 1982 Malvinas war, Argentina under a military dictatorship has been the largest military spender in Latin America. In contrast, democratically-elected President Alfonsín has relied on the treaty to complement his campaign for cutting military expenditures. The weaker party, Chile, while still under a military government, has welcomed a less tense military situation with Argentina because of internal problems and continuing disputes on its northern borders. In a strategic part of the continent, the treaty may therefore help curb arms proliferation and use. In a continent where disputes tend to be interlocking, a contagion effect for peace could occur. Just as the 1982 Falklands/Malvinas war heightened tension throughout the continent, the 1984 treaty could play a significant role in easing regional tension.


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### Acknowledgments

Permission was kindly granted by the editors of the *Ocean Yearbook* to use a revised version of several paragraphs that appeared in another article by the author, "EEZ Policy in South America's Southern Cone," in *Ocean Yearbook* 6, Elizabeth Mann Borgese and Norton Ginsburg, eds. Chicago: University of Chicago Press, 1985.

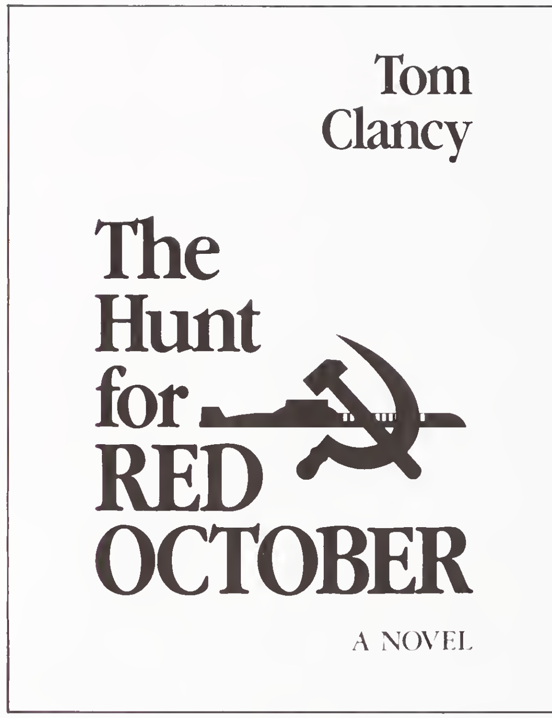
# book reviews

**The Hunt for Red October by Tom Clancy. 1984. The United States Naval Institute Press, Annapolis, Maryland. 387 pp. $14.95.**

This novel, the first for the author and the first published by the U.S. Naval Institute Press, is an exciting modern sea yarn based on the complexities of antisubmarine warfare. The reader—there have been some 150,000 to date over several printings—is brought to the brink of a nuclear exchange by a plot that turns on a top Soviet naval officer's attempt to defect to the United States in a new ballistic missile submarine—called a "boomer" in Navy parlance.

The Soviet sub—*Red October*—is equipped with a new propulsion system that allows it to run so silently as to be almost undetectable acoustically. The novel thus will be appreciated by those of the high tech persuasion as well as those interested in the underwater aspects of military strategy. Nearly the entire Soviet Atlantic fleet is ordered to find and destroy *Red October*, while the U.S. fleet's orders are to find the sub and bring it safely to port. The hunt lasts 18 days and covers more than 4,000 miles of ocean.

When I was at this year's meeting of the U.S. Naval Institute (held in April at the War College in Newport, R.I.), high-ranking naval officers commended the author for his "plausible scenario." Tom Clancy was depicted as a married




insurance salesman from Delaware with three children. He had never been in a submarine until after submitting his manuscript to the editors of the Naval Institute Press. Hard to believe, although one of his editors said Clancy was "helped" with some details in the interest of authenticity. One always wonders with this type of book if it is fiction based on imagination or on fact.

The Woods Hole Oceanographic "Institute" [sic] and its deep submergence research vehicle *Sea Cliff* [pseudonym] play a small role in the scenario. These passages will undoubtedly bring smiles to the lips of those here at the Institution reading this work.

Probably the most disturbing aspect of this novel is that when you put it down you are left with the uneasy feeling that a miscalculation or mistake in the real world of antisubmarine warfare could lead to thermonuclear war. The novel makes the point that these naval systems are very elaborate and complex, and that the time available to respond to a crisis is almost always dictated by the other side.

The weakest sections of *Red October* are the parts in which the author engages in propaganda, crowing over the virtues of the American society as compared to the Soviet. These passages, for my part, could have been eliminated; they were inferable from the rest of the text. Their omission would, I think, have made the work stronger, more believable. The ending, too, was somewhat melodramatic. These are small criticisms though. In general, I found the novel interesting on several levels—that of a general reader looking for a fast moving, entertaining sea yarn, that of a person concerned about the repercussions of

advanced technology, and that of an individual seeking a glimpse into the highly specialized world of antisubmarine warfare.

**Paul R. Ryan,**
**Editor, *Oceanus***

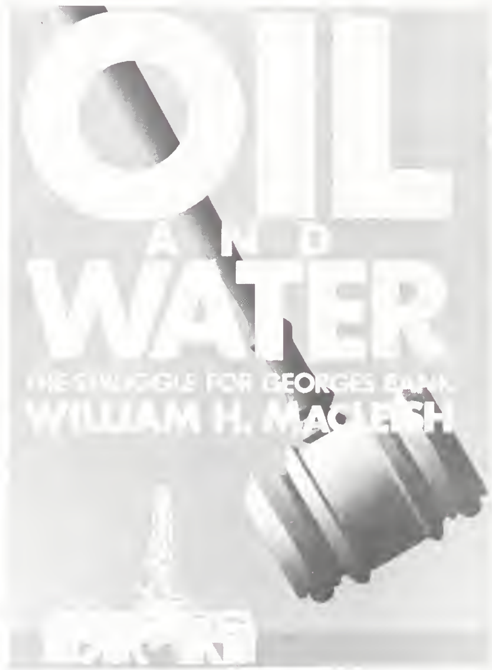
***Oil and Water: The Struggle for Georges Bank* by William H. MacLeish. 1985. The Atlantic Monthly Press, Boston, Mass. 304 pp. + xv. $19.95.**

This book examines the conflict between users of two different resources that exist in the same place. The resources are fish and oil; the locale is Georges Bank. It should be noted that the existence of the oil is "theoretical," and estimates of the resource are reduced yearly. The author, who is a former editor of *Oceanus*, characterizes this conflict as a "resource revolt," with the fishermen identified as the insurrectionists and the oil men identified as the loyalists.

William H. MacLeish uses two strategies or approaches to examine this conflict. First, he provides short historical accounts of the important landmark events that have occurred *vis-à-vis* attempts by the federal government to initiate oil and gas development on Georges Bank. These events have been political (for example, the election of Edward King to the governorship of Massachusetts), administrative/regulatory (example, the acceleration and expansion of the federal offshore leasing program by Secretaries of the Interior Andrus and Watt), and legal (the issuance of injunctions against the Georges Bank lease sales by federal court justices). Second, MacLeish provides us with verbal snapshots on several of the main actors or groups involved in the "resource revolt" over Georges Bank. To acquire these snapshots, MacLeish has played the role of participant/observer/interviewer on fishing vessels, research vessels, Coast Guard surveillance helicopters, and offshore oil rigs. He also attended public hearings, court proceedings, and lease sales, and augmented his knowledge with visits to the offices of state and federal bureaucrats and corporate executives. To provide continuity to his story, MacLeish has interwoven the historical episodes with the anecdotal material from his stints as "fisherman," "oil man," "research scientist," and so forth.

Unfortunately, at least for this reader, the interweaving of the history with the "work biographies" does not succeed, even though MacLeish's descriptions of the motivations and feelings of the participants are unparalleled. My negative appraisal stems from the history of oil and gas development on Georges Bank presented by the book. All of the events are there, all of the key decisions are described, but too summarily. Important aspects of the battle for the resource future of Georges Bank are dealt with almost as asides or afterthoughts. An example of this is the description of Rhode Island's position on the issue of oil and gas development. MacLeish only commits a few sentences to the fact that Rhode Island has vigorously supported federal efforts to develop oil and gas resources on Georges Bank. The state has done so in the hope that the depressed economy of southern Rhode Island would prosper as an onshore support area for the offshore activities. Could it be that in setting up a discussion of federal-state conflict over Georges Bank, MacLeish has opted to ignore instances of federal-state cooperation?

A second example of the book's inadequacy in terms of the legal and administrative history of Georges Bank development is MacLeish's treatment of *California* v. *Watt*. This case dealt with the ability of a state to block a federal activity if the activity was directly affecting its coastal zone in a manner contrary to that state's coastal zone management plan. The decision reached by the U. S. Supreme Court is truly a landmark against which all future offshore oil and gas development will be checked. In essence, the Supreme Court decision declares that a lease




sale does not fall under the "consistency provisions" of the federal Coastal Zone Management Act. The ramifications of this decision, not only for Georges Bank, but for the entire U.S. outer continental shelf, are many. MacLeish certainly should have devoted more than two sentences to the final outcome of *California* v. *Watt*.

If I had been MacLeish's editor, I would have suggested abandoning the historical material; the length of the book does not allow for a full treatment of it. Further, there are many other superior sources on the historical aspects, but none on the people.

Thus, a short introductory chapter would have sufficed to set the background for the real strengths of this volume. The principals in MacLeish's vignettes are interesting, informative, and humorous. The anecdotes provide fresh insight into the nature of those who have invested time and money in Georges Bank and its resources. That is the real story of *Oil and Water*. What MacLeish has done, through years of intimate observation, is to provide us all with a better understanding of the people behind the headlines, court orders, and Federal Register regulations. And when all is said and done, perhaps an enhanced appreciation of the human beings involved is more important than full knowledge of the legal, economic, and scientific issues.

What MacLeish clearly demonstrates with his "work biographies" is that Georges Bank is not inhabited by "insurrectionists" and "loyalists." Rather, the individuals involved in the resource conflict are dedicated and sincere;

they are interested in Georges Bank because it is important to their livelihoods and ways of life.

Although I have found fault with this book's treatment of the legal and political aspects of Georges Bank oil and gas development, it cannot be faulted for its treatment of the human aspects. I can, therefore, recommend it to anyone with an interest in the ocean and its resources and the people who exploit, protect, study, and manage those resources.

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**Woods Hole, Mass.**

***Design and Construction of Mounds for Breakwaters and Coastal Protection.*** **Per Bruun, ed. 1985. Elsevier Science Publishing Co., New York, N.Y. 938 pp. + xxiv. $92.75.**

On average, relative sea levels worldwide have been rising for the past century, and will continue to rise for the predictable future. Accompanying this sea-level rise has been widespread coastal change, with erosion surpassing accretion. In an attempt to slow this erosion, and to allow man to continue his encroachment onto the coastal zone, various structural engineering alternatives have been formulated to stem the forces of the ocean. These structures, including breakwaters, jetties, revetments, seawalls, groins, and other mounds of various nomenclature, have been designed through empirical means over the last century or so, to retard the ocean's encroachment onto land and to provide protected ports and harbors. Advancing through trial and error, this approach has suffered many failures, which in turn have guided the way toward improvements in coastal protection. Today, the coastal engineer continues to use empiricism to design structures in the coastal zone, with varying degrees of success.

The present text, edited by Per Bruun, is an attempt to collate the more recent quantitative advances in design and construction of "mounds" for coastal protection works, to emphasize the science rather than the art of coastal protection design. Recent advances in theoretical hydrodynamics, analysis and design of structures, and construction techniques have improved the potential success rate of coastal structures in resolving coastal erosion and transportation problems. This book attempts to provide this information to the coastal engineer on all levels, making the diversity of engineering advances and expertise available in a single volume.

Written by a number of international experts in the field of coastal engineering (whose individual contributions generally are impossible to determine, unfortunately, because of the editing), the major headings include basic parameters for design, in which wave and structures concepts are reviewed; design, incorporating theory and empiricism; construction, discussing techniques, equipment, and various other considerations; examples of mound breakwaters, including failures; coastal protection structures from design to construction; and finally a section on alternative designs of mounds using bituminous materials. Most sections include not only engineering analyses, but also techniques for risk analysis, economic design, and factors affecting duration and cost of projects. Given the list of contributors, these sections offer some insightful material of general interest to the coastal engineer.

The utility of the book is hampered by several factors, decreasing its appeal to the engineering audience. The organization of the book is weak, with related subjects scattered throughout the volume, instead of placed under a single heading. This is partly the result of having many authors, I would suspect. The layout is unappealing, with little effort placed on identifying major and minor headings within the book. Consequently, it is difficult to identify the structure of the book when reading, leading to some confusion. Perhaps even more harmful, however, is the poor quality of print, which varies throughout the book. Differences in type and density of print detract from the readability of the book, and compound the problems of disorganization. The book includes many figures, many of which have symbols that are undefined in the caption as well as the text itself. Some figures are of poor quality, hard to read, and inappropriately laid out. Other figures (and tables) are included without adding significantly to the subject.

One of the major drawbacks of the text is the lack of an appendix defining all mathematical symbols used in the book. Symbols are not standardized, and are often used but not defined in a particular section. This means that one has to search long and hard (given the organizational problems) to pin down the meaning of many symbols. A simple appendix defining each symbol would be helpful, and standardizing (which is an editorial job) would increase the readability even more.

There are several sections in the book that are only marginally germane to the subject material, but which are included in their entirety, leading to a significant loss of continuity. Examples are a discussion by O. G. Houmb on wave statistics, and a section by Dagfin Brodtkorb on a microwave sensor for the ocean. These digressions severely impact on the organization of the book, rather than making the book more complete, as I suspect the original intent may have been.

In summary, Per Bruun has edited a book that has much information of widespread utility to coastal engineers throughout the world, but whose presentation will probably prevent it from being a widely used reference text. The niche for a well-written design text covering coastal structural design and construction therefore remains open, leading to the hope that another editor will be able to provide a more useful volume, or that Per Bruun will edit the present text more seriously to remove its many faults. Sea level will continue to rise, and coastal erosion will continue in the future. Although a purely structural solution to resolve these sea level/erosional problems is unwise, structural measures will continue to be a valuable alternative in our arsenal of means to mitigate rising sea levels and resultant coastal change. Coastal engineers must continually strive to improve their knowledge and implementation of these structural measures. For this, the engineers need updated, readable, well-written texts to keep them abreast of advances, all areas in which the present text falls short.

**David G. Aubrey,**
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# Books Received

## Biology

***11th International Seaweed Symposium*, C. J. Bird and M. A. Ragan, eds. Developments in Hydrobiology 22. 1984. Dr W. Junk Publishers, Kluwer Boston, Boston, Mass. 621 pp. + xxxi. $128.50. £88.95.**

Held in Qingdao, People's Republic of China, in June 1983, this symposium was a large affair with many international participants. The resulting book contains five opening addresses, and is divided into three parts. Part One contains three plenary lectures. Part Two (minisymposia—special topic sessions) contains 29 papers under these headings: taxonomy of *Gracilaria*; cultivation biology of *Gracilaria*; utilization of seaweeds and their products; production and utilization of microalgae; algae in medicine and pharmacology; chemistry of agars and carigeenans; and biology of *Acetabularia*. Part Three (contributed papers) contains 91 papers under these headings: morphology, taxonomy and life histories, cultivation, resources and management, ecology, fouling organisms and pathology, physiology, chemical composition and properties, and chemical structure and characterization.

***Sea Otters: A Natural History and Guide* by Roy Nickerson. Chronicle Books, San Francisco, Calif. 110 pp. $7.95.**

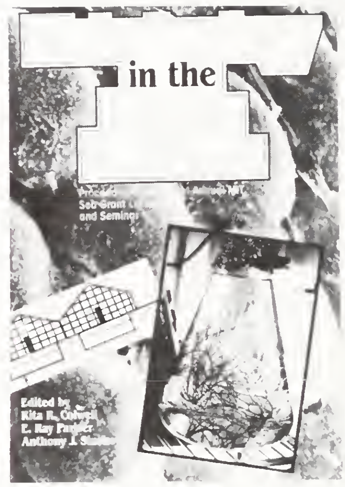
A small book sprinkled with full-page, black-and-white photos. The natural history of sea otters is the theme, including their near extinction in the earlier part of this century. Sea otters are playful, comic creatures who seem to get enjoyment from life. Although they have recovered in numbers somewhat, their future is still uncertain because of commercial fishermen's dislike for them. This book explains it all, and suggests good places to go to observe sea otters along the west coast of the U.S. Judging by the picture captions, Monterey, California, is a good bet.

***Shorebirds: Breeding Behavior and Populations* and *Shorebirds: Migration and Foraging Behavior*, Joanna Burger and Bori L. Olla, eds. 1984. Volumes 5 and 6 of Behavior of Marine Animals, Plenum Press, New York, N.Y. Vol. 5: 437 pp. + xv. $59.50. Vol. 6: 329 pp. + xiv. $49.50.**

Shorebirds are closely related taxonomically, but exhibit great diversity in behavior and ecology. This makes them good subjects for studies of behavior, ecology, and evolution. In the last 20 years many such studies have been conducted; these two volumes provide a selection of current research in the field. In Volume 5, the first two chapters introduce both books, discussing shorebird classification and the concept of shorebirds as marine animals. Chapters 3 through 9 focus on aspects of shorebird breeding behavior, including topics such as breeding site fidelity, polyandrous mating systems, and communications. Population dynamics and conservation of shorebirds also are covered in Volume 5. The six chapters of Volume 6 are primarily on behavior patterns of shorebirds during the non-breeding season, including migration patterns and influences, foraging and activity patterns, and the spacing behavior of non-breeding shorebirds.

***Skin Diver Magazine's Book of Fishes* by Hillary Hauser. 1984. Pisces Books, New York, NY. 192 pp. $24.95.**

The fishes in this book are presented phyletically, beginning with the more primitive and proceeding to the more complex. The book evolved out of the "Fish of the Month" column in *Skin Diver*. Each two-page spread is illustrated with a full-page color photograph and a line drawing. Each fish family is identified by its common name or names, with the scientific name printed underneath. General remarks, range and habitats, life cycle and diet, and physical characteristics (or some variation on this outline) are given for each group. Some descriptions have a map depicting the fish's general range. There are at least 49 kinds of fish represented, from tarpons and ladyfishes to puffers, porcupine fishes, and molas.




***Biotechnology in the Marine Sciences: Proceedings of the First Annual MIT Sea Grant Lecture and Seminar*, Rita R. Colwell, Anthony J. Sinskey, and E. Ray Pariser, eds. 1984. John Wiley & Sons, New York, N.Y. 293 pp. + xvii. $37.50.**

This book contains papers from a conference on new ideas for increasing and diversifying marine food products and pharmaceuticals and protecting against pollution and marine fouling, by incorporating genetic research, biochemistry, and ocean engineering. The book begins with an introduction to biotechnology in the marine sciences, then has four parts comprising papers from the seminars at the conference. The general topics are: aquaculture; marine pharmaceuticals and bioproducts; marine biofouling; and marine pollution control.

***A Functional Biology of Sticklebacks* by R. J. Wootton. 1984. University of California Press, Berkeley and Los Angeles, Calif. 265 pp. $29.75.**

By examining how the stickleback makes use of its habitat, food supply, and time, and its patterns of growth, survivorship, and reproduction, the author demonstrates that, in ecology and evolutionary biology, a theoretical framework can be used to illuminate the ways in which animals function and to show that knowledge obtainable only through

detailed study of a taxon is required to test such a theoretical framework.

***A Functional Biology of Free-Living Protozoa*** **by Johanna Laybourn-Parry. 1984. University of California Press, Berkeley and Los Angeles, Calif. 218 pp. + viii. $27.50.**

All the life-sustaining processes carried out in the metazoa by tissues and organs are performed in the protozoa by organelles. This book examines how ciliates, sarcodines, and flagellates acquire energy, and discusses how they perform various physiological processes (growth, reproduction, osmo-regulation, and such). The important integration of physiology and ecology among the protozoa is detailed.

***Watching Fishes: Life and Behavior on Coral Reefs*** **by Roberta Wilson and James Q. Wilson. 1985. Harper & Row, New York, N.Y. 275 pp. $25.00.**

Written for general readers, this book discusses in easy terms scientific knowledge of coral reefs and the behavior of fishes found there. The authors describe and explain coral reefs, then devote most of the book to the fishes, explaining their swimming, eating, sensory perception, social life, and more. Two inserts of color plates and many sketches by R. Wilson illustrate the book. A glossary is included, along with an extensive reference list for those wishing to delve further into the subject.

## Chemistry

***Organic Chemicals in Natural Waters: Applied Monitoring and Impact Assessment*** **by James W. Moore and S. Ramamoorthy. 1984. Springer-Verlag, New York, N.Y. 289 pp. + xi. $39.80.**

This is the second of two volumes reviewing data, methods, and principles of potential use in environmental management and research. The book covers the organic chemicals outlined in the EPA's priority pollutants list and Canada's Environmental Contaminant Act. Most of the chemicals—aliphatic and aromatic compounds, chlorinated pesticides, petroleum hydrocarbons, etcetera—are widespread in the environment and are toxic to humans and fish. Included for each chemical are reviews of the chemistry, production, uses, discharges, behavior in natural waters, uptake, and toxicity. Also included are description criteria for prioritizing chemical hazards posed to users of aquatic resources. There are four appendices to aid readers: chemical formulae, physical and chemical terms, common and scientific names of fishes, and equations for evaluating physico-chemical fate processes.

***Geochemistry of Organic Matter in the Ocean*** **by Evgenii A. Romankevich. 1984. Springer-Verlag, New York, N.Y. (Originally published in Russian by Vestnic Academii Nauk SSSR, 1978.) 334 pp. + xv. $59.00.**

Using a systems-analysis approach, this book covers the distribution, composition, transformation, interrelations, balance, and fate of organic matter in the oceans—including living, dissolved, colloid, and suspended organic matter in both bottom sediments and in interstitial waters. There are nine chapters about organic matter in the ocean. The chapters are on sources, the carbon of dissolved and particulate organic matter, organic carbon of Late Quaternary sediments in seas and oceans, nitrogen and phosphorus in the process of sedimentogenesis, proteinaceous compounds and amino acids, carbohydrates, and more.

## Environment/Ecology

***The Estuary as a Filter*****, Victor S. Kennedy, ed. 1984. Academic Press, Orlando, Fla. 511 pp. $39.50; £30.50.**

Occupying less than one percent of our planet's surface, estuaries illustrate that the "sum is greater than the parts"—they are unique, complex, and very important to the total environment. The papers in this volume are grouped as they were presented at the seventh biennial conference of the Estuarine Research Federation, held in Virginia Beach, Virginia, October 1983. There are five sections: physical processes, chemical processes, chemical-geochemical processes, biological processes, and management implications. There are 23 papers altogether, each of which somehow addresses the idea of estuaries as filters—traps for materials.

***External Costs of Coastal Beach Pollution: An Hedonic Approach*** **by Elizabeth A. Wilman. 1984. Resources for the Future, Washington, D.C. 194 pp. + xiii. $15.00.**

What would a major oil spill on Georges Bank (off the coast of Massachusetts) cost in beach recreational services? In this book, the author develops a method for estimating such a loss monetarily, combining oil-spill risk analysis with a model of tourist pricing on Cape Cod and Martha's Vineyard. To do this requires eight chapters and five appendices. After introducing the problem by discussing management needs and "economic valuation of externalities," the author introduces the case study, presents the hedonic pricing model and the oil-spill risk-analysis model, discusses risk and uncertainty in decisionmaking, presents an econometric analysis of the hedonic model, combines the results, and presents conclusions and recommendations. The appendices present various data and lists of information relevant to the work.

***The Antarctic Circumpolar Ocean*** **by George Deacon. 1984. Studies in Polar Research, Cambridge University Press, New York, N.Y. 180 pp. + viii. $24.95.**

This small, informative book is illustrated with black-and-white diagrams and photos. Though it's intended for students going into oceanography or polar research, it is suitable for other readers as well. The author means to show how present knowledge grew from earlier findings; the first part of the book discusses early ideas and evidence of a great southern continent, the history of Antarctic exploration, whaling and sealing in the Southern Ocean through the early 20th century, and the systematic studies of oceanographic expeditions. The second part of the book examines Antarctic water movements, biological productivity, distributions of marine plants and animals, climate, and ice cover.

***Estuarine Ecology of the Southeastern United States and Gulf of Mexico*** **by Robert R. Stickney. 1984. Texas A & M University Press, College Station, Texas. 310 pp. + xii. $24.50.**

An examination of the physical, chemical, geological, and biological

characteristics of estuaries. Many Americans live in cities located near estuaries—coastal regions where fresh and salt water mingle—but few of us understand estuaries or their contribution to the quality of life. All that can be rectified by reading this book, which, though it concentrates on estuaries of the southern U.S., contains information relevant to most U.S. estuaries. The 11 chapters are extensively referenced, and despite the voluminous data presented, the book is written so as to be accessible to any interested reader. Topics covered are: marine and estuarine science, freshwater inflow, sedimentary processes, physical relationships, estuarine chemistry, primary producers, decomposers and detritus, zooplankton, benthos, fishes, higher vertebrates, and man's impact on estuaries.

***Coastal and Sedimentary Environments*, Richard A. Davis, Jr., ed. 1985. Second edition. Springer-Verlag, New York, N.Y. 716 pp. + xvii. $39.80.**

Bays, estuaries, deltas, marshes, dunes, beaches: many environments make up the coastal zone, where land and sea meet. To utilize this area well, yet not plunder it, we need extensive knowledge of its complexities. This book is designed to provide appropriate background knowledge for geologists, engineers, oceanographers, coastal managers, and others concerned with the coastal zone. Each of the nine chapters is on one coastal environment, covering occurrence and distribution, formation, and various physical processes. The 10th chapter, "Modelling Coastal Environments," covers various kinds of coastal models—statistical, deterministic, storm, and so forth.

***Diving and Marine Biology: The Ecology of the Sublittoral* by George F. Warner. 1984. Cambridge Studies in Modern Biology 3. Cambridge University Press, New York, N.Y. 210 pp. + xii. $39.50.**

This book is intended for divers and non-divers, describing the environment with which divers are most familiar (from low tide down to about 60 meters). Scuba diving has made a special contribution to marine biology, because scuba permits marine biologists to explore the seabed in person. This book has four parts: hard substrates (with chapters on physical factors and communities, adaptations of organisms to the movement of water, and biological interactions); kelp forests (plants and fauna); coral reefs (reef structure and environment, nutrition and growth of reef corals, biological interactions with reef corals, and reef fish); and level substrates.

***Lake Biwa*, Shoji Horie, ed. 1984. Monographiae Biologicae Volume 54, Dr W. Junk Publishers, Kluwer Boston, Boston, Mass. 654 pp. + xi. $145.00; £88.95.**

The limnology of the biggest lake in Japan, thought to be five million years old (making it one of the oldest lakes on Earth). After considering the general features of Lake Biwa, this compendium of 37 papers covers the lake's geological features, modern limnology, paleolimnology, biogeography, and the influence of human activities on the lake.

***Fundamentals of Aquatic Toxicology: Methods and Applications*, Gary M. Rand and Sam R. Petrocelli, eds. 1985. Hemisphere Publishing Corporation, New York, N.Y. Distributed outside the United States by McGraw-Hill International Book Company, London, England. 666 pp. + xviii. $69.95.**

Useful as a text and reference for students and workers in aquatic toxicology, this book has information about aquatic biology and ecology, invertebrate and fisheries biology, and environmental and pollution biology. The 23 chapters are divided into five parts: toxicity testing (concepts and methods); sublethal effects; specific chemical effects; chemical distribution/fate; and hazard evaluation. Specific laws and regulatory agencies are identified, and a glossary of terms is included.

***Offshore and Coastal Modelling*, P. P. G. Dyke, A. O. Moscardini, and E. H. Robson, eds. 1985. Lecture Notes on Coastal and Estuarine Studies 12, Springer-Verlag, New York, N.Y. 399 pp. + ix. $32.80.**

The papers published in this book are from the seventh Polymodel Conference, held in May of 1984. Polymodel is the NorthEast of England Polytechnic's Mathematical Modelling and Computer Simulation Group. The volume's 18 chapters are in four parts: Chapters on tides, storm surges and coastal circulations; chapters on coastal engineering modelling, discussing phenomena like beach erosion and non-linear waves; chapters on offshore structures, including connections between structures; and two chapters on offshore corrosion problems.

***Concepts in Marine Pollution Measurements*, Harris H. White, ed. 1984. Maryland Sea Grant Publications, University of Maryland, College Park, Md. 743 pp. + xii. $12.50.**

Techniques for measuring marine pollution and marine pollution's effects. The 41 papers in this volume were culled from those given at a workshop on "Meaningful Measures of Marine Pollution Effects" held in Pensacola, Florida, in 1982. The authors were asked to elaborate on the strong features and weak points of whole categories of techniques. The resulting papers are organized into these groups: toxicity tests, laboratory microcosms, community parameters and measures of community impact, bioaccumulation tests, chemical measurements and effects criteria, anomalies in field specimens, mesocosms and field systems, and field monitoring programs. Each section has an introductory paper; a summary chapter ends the book.

## Fisheries

***Fishery Management* by J. L. McHugh. 1984. Lecture Notes on Coastal and Estuarine Studies 10, Springer-Verlag, New York, N.Y. 207 pp. $17.00.**

This text evolved out of the course on fishery management that the author teaches at the State University of New York, Stony Brook. An introduction to world fisheries begins the book; there are chapters on marine fishery research and a general chapter on fisheries of the United States. Case studies of the oyster, blue crab, Pacific sardine and Atlantic menhaden, marine sport fisheries, and various compacts and conventions make up the bulk of the book.

***Evolution of Fish Species Flocks*, Anthony A. Echelle and Irv Kornfield, eds. 1984. University of Maine at Orono Press, Orono, Maine. 257 pp. + x. $28.95 (hardcover); $20.95 (paperback).**

Common descent and coexistence in the same lake characterize lacustrine

species flocks. This book includes 18 papers by 27 contributors to a symposium that addressed the following questions: Can the presence of scores, if not hundreds, of closely related species in a single lake be explained by allopatric speciation? Do these species flocks refute the principle of competitive exclusion? Partial answers were obtained, and the remaining problems clarified. For those still confused about what a species flock is, the first paper addresses just that. Other topics include: Semionotid fishes from the Mesozoic Great Lakes of North America; African Cichilids and evolutionary theories; and much more. A final chapter, "Who's Tending the Flock?" by the book's editors, discusses natural and anthropogenic aspects of extinction in fish species flocks, stressing the need for scientists' active involvement in species flocks' conservation.

***Exploitation of Marine Communities,* R. M. May, ed. 1984. Springer-Verlag, New York, N.Y. 366 pp. + x. $20.00.**

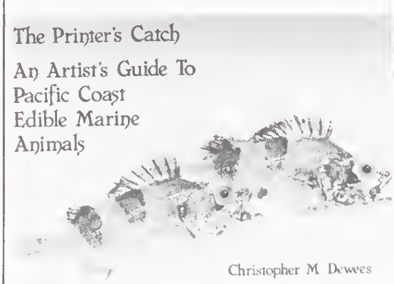
The report of the Dahlem Workshop on exploitation of marine communities held in Berlin in April, 1984. This volume surveys our understanding of the dynamics of multispecies marine ecosystems and explores implications for fisheries management, with background papers and rapporteurs' reports of group discussions. The book begins with biological accounts of the genetics and dynamics of single populations and of multispecies systems, then moves on to discuss management under uncertainty and the biological, economic, and social factors that roil together in the management of multispecies systems. Throughout, the emphasis is on identifying questions and potentially fruitful areas of new research. Complete with four group photographs, 42 figures, 14 tables, and a minimum of equations, this book should appeal to a wide readership.

## General Reading

***A Scientist at the Seashore* by James Trefil. 1984. Charles Scribner's Sons, New York, N.Y. 208 pp. + ix. $16.95.**

In this conversationally written book, the author guides the reader on a stroll along the seashore, pointing out a few interesting phenomena along the way. In the process, Trefil makes side excursions to Pluto, Venus, and other solar systems. By examining common mysteries encountered on trips to the beach—such as the dynamics of tides, skipping stones, dunes, and waves, and the saltiness of the water—the author illuminates some complicated aspects of physics in a readable manner.

***The Printer's Catch: An Artist's Guide to Pacific Coast Edible Marine Animals* by Christopher M. Dewees. 1984. Sea Challengers, Monterey, Calif. 112 pp. $26.95.**




This book combines art with nature. People who enjoy *gyotaku* (fish prints) often want to know more about fish, and this book provides just that—summaries of the natural histories of fishes from sharks and rays to shrimp, all illustrated by fish prints. There are more than 30 types of fish represented, including surfperch, barracudas, scallops, and oysters, with 63 color plates of prints. A knowledge of fish natural history is important for making good fish prints, and the prints themselves can be helpful to biologists. A beautiful book, by a fishery biologist, equally suitable for those interested in fish and those interested in art. The book includes directions for making prints, a glossary, and illustrations of fishing gear.

***Shallow Waters: A Year on Cape Cod's Pleasant Bay* by William Sargent. 1985. Parnassus Imprints (paperback edition; original hardcover published 1981 by Houghton Mifflin), Orleans, Mass. 138 pp. + xix. $12.95.**

A season-by-season chronicle of life in this bay, located behind Nauset Beach on the Atlantic Ocean side of Cape Cod. The author spent boyhood and manhood summers on Pleasant Bay, which he calls a microcosm of the universe. The book is illustrated with plenty of black-and-white photographs and a six-page color insert. Each of the four sections (Spring, Summer, Fall, and Winter) is subdivided into essays on individual topics, five or six to a section, excepting Winter which has only two. Perhaps this is a subtle hint about the duration of winters on Cape Cod.

## Geology

***The Shape & Form of Puget Sound* by Robert Burns. 1985. Puget Sound Books, Washington Sea Grant, Seattle, Wash. 100 pp. $8.95.**

Although geological studies of specific areas are usually of limited interest, this book may prove an exception. The author uses geologic terms well, making them understandable without burdening the text with definitions. Furthermore, in the course of explaining the geology of Puget Sound and adjoining waters, he elucidates many general geologic processes. The reader learns geologic concepts and immediately is able to apply them to an interesting case study—a truly enlightened way to write a book!

## Marine Policy

***The Oslo and Paris Commissions: The First Decade—International Cooperation in Protecting Our Marine Environment.* 1984. Oslo and Paris Commissions, London, England. 377 pp. + x. Price unknown.**

Last year marked the 10th anniversary of the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (the Oslo Convention), which was followed by the Paris Convention for the Prevention of Marine Pollution from Land-Based Sources. This volume describes some of the progress made in the name of these two conventions. Belgium, Denmark, Finland, France, Federal Republic of Germany, Iceland, Ireland, Netherlands, Norway, Portugal, Sweden, and England—contracting parties to the conventions—have provided summaries of their national policies toward waste control. Each summary contains a brief, general introduction to the nation, with a statement on the waste problem and

waste disposal policy of that nation; a section on the organizational framework for waste disposal in that country, covering the legal basis and administrative structure; a section on the waste problem, covering municipal, industrial, and agricultural wastes and dredged materials; a section on waste treatment and disposal methods (on land, to the atmosphere, into waters, recycling and reuse, and reduction at source); a section considering special problems (radioactive waste); and sections on monitoring and surveillance and present and future policy. The book ends with an outline of the events in 1971 that led to the Oslo Convention, a history of the Oslo and Paris Commissions to 1984, an outline of pertinent information on the European Economic Community, a list of general conclusions, and a look at the future of the two conventions.

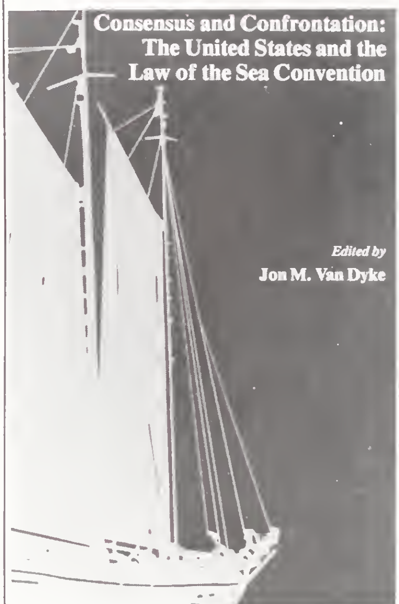
***Living with Long Island's South Shore* by Larry R. McCormick, Orrin H. Pilkey, Jr., William J. Neal, and Orrin H. Pilkey, Sr. 1984. Duke University Press, Durham, N.C. 157 pp. + xiii. $22.75 (hardcover); $9.75 (paperback).**

This book should be required reading in every home on Long Island. Part of the extremely useful Living with the Shore series put out by Duke University Press, *Living with Long Island's South Shore* delineates those areas of Long Island most threatened by erosion and storm damage and explains why. Additional information shows how man affects the shoreline, how to evaluate the safety of a particular beach house, and some construction techniques to consider in building or renovating a house on the shore.

***Coasts: Institutional Arrangements for Management of Coastal Resources* by Jens C. Sorensen, Scott T. McCreary, and Marc J. Hershman. 1984. Research Planning Institute, Columbia, S.C. 165 pp. + xiv. $21.00.**

This fairly technical work on coastal planning is likely to be of great interest to those actively involved with the subject, and of little interest to lay readers. The authors analyze strategies common around the world for managing coastal zones, and devote a chapter to defining terms that crop up repeatedly in both this book and much other planning literature. Another quite useful chapter outlines criteria that help assure success in coastal management.

***Consensus and Confrontation: The United States and the Law of the Sea Convention*, Jon M. Van Dyke, ed. 1985. Workshop of the Law of the Sea Institute, University of Hawaii, Honolulu, Hawaii. 576 pp. + x. $29.50.**




Persistent doubts about the U.S. decision not to sign the Law of the Sea Convention, and a desire to look at the benefits and costs of the convention as a whole, led to the holding of a week-long workshop in Honolulu in January 1984, to analyze all aspects of the convention. Representatives of the Reagan Administration, diplomats from the Asia-Pacific region (developing nations, Pacific island nations, the Soviet Union, and China), and the U.S. mining industry presented their concerns. U.S. academicians in attendence analyzed the competing positions of all sides; discussions followed. The papers and discussions in this book were organized and edited to suit the publication, grouping materials by topic.

## Ships and Sailing

***Battleships in Transition: The Creation of the Steam Battlefleet 1815–1860* by Andrew Lambert. 1984. Naval Institute Press, Annapolis, Md. 161 pp. $18.95.**

The history of warship development includes a bizarre intermediary, the steam line-of-battle ship, that was used in the mid-19th century. This wooden sailing ship with steam engine preceded the ironclad in history. Lambert's book is a study of the evolution and active service of the wooden steam battleship, discussing both historical and physical particulars, with emphasis on the steam line-of-battle ship's contribution to developing naval technology, and the factors that caused the ship's sudden demise. The author considers both political and administrative decisions that determined design, fleet size, and other details.

***Oregon Shipwrecks* by Don Marshall. 1984. Binford & Mort Publishing, Portland, Ore. 235 pp. + ix. $24.95.**

In 200 years, the Oregon coast has claimed hundreds of ships and human lives. This book outlines the shipwrecks, from the earliest recorded (about 1705) to 1955. The author describes the events of various wrecks in a speculative manner, intertwining facts specific to individual wrecks with quotations from witnesses, diaries, and letters.

- **Senses of the Sea,** Vol. 23:3, Fall 1980—A look at the complex sensory systems of marine animals.
- **Summer Issue,** Vol. 23:2, Summer, 1980—Plankton distribution, El Niño and African fisheries, hot springs in the Pacific, Georges Bank, and more.
- **A Decade of Big Ocean Science,** Vol. 23:1, Spring 1980—As it has in other major branches of research, the team approach has become a powerful force in oceanography.
- **Ocean Energy,** Vol. 22:4, Winter 1979/80—How much new energy can the oceans supply?
- **Ocean/Continent Boundaries,** Vol. 22:3, Fall 1979—Continental margins are being studied for oil and gas prospects as well as for plate tectonics data.
- **The Deep Sea,** Vol. 21:1, Winter 1978—Over the last decade, scientists have become increasingly interested in the deep waters and sediments of the abyss.
- **Sound in the Sea,** Vol. 20:2, Spring 1977—The use of acoustics in navigation and oceanography.

**1984. Research Planning Institute, Columbia, S.C. 165 pp. + xiv. $21.00.**

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***Battleships in Transition: The Creation of the Steam Battlefleet 1815–1860* by Andrew Lambert. 1984. Naval Institute Press, Annapolis, Md. 161 pp. $18.95.**

The history of warship development includes a bizarre intermediary, the steam line-of-battle ship, that was

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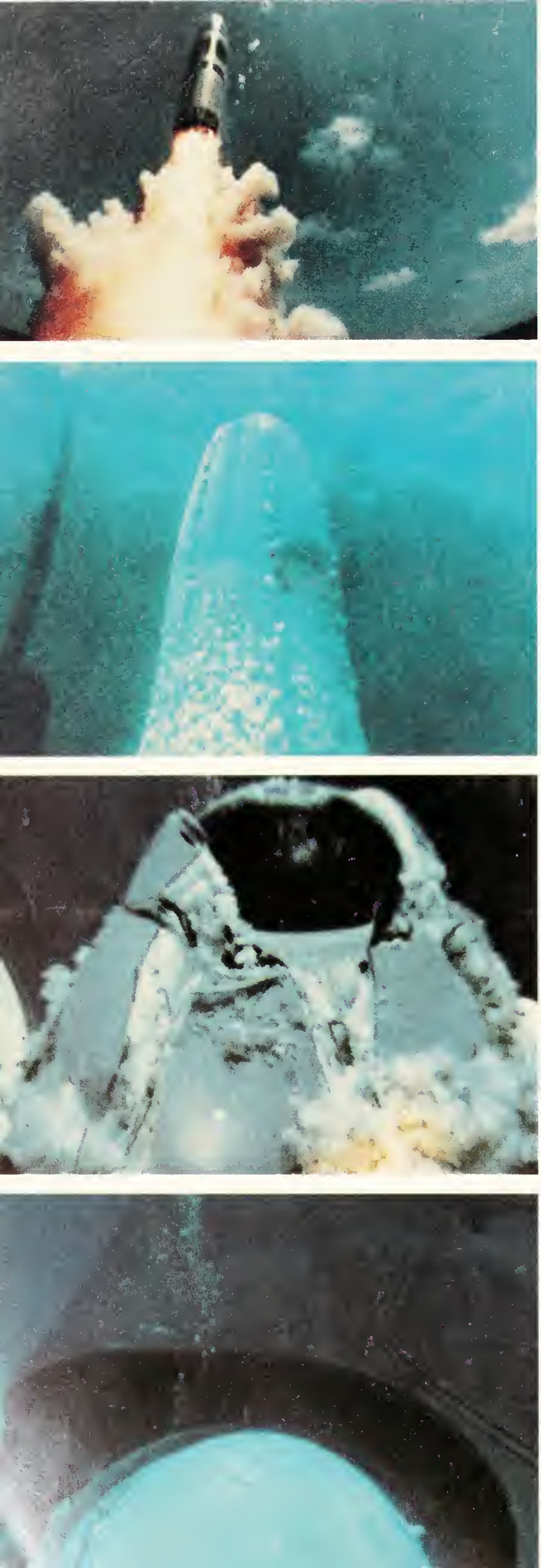

**Trident missile submerged launch sequence**